# The Development of a Hybrid Knowledge-Based System for Lean Six Sigma Implementation in Healthcare Environment

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The Development of a Hybrid Knowledge-Based (KB)/Gauging Absence of Pre-Requisites (GAP)/Analytical Hierarchy Process (AHP) Model for Implementing Lean Six Sigma System in Healthcare Environment

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**Abstract**

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**Thesis Title:** The Development of a Hybrid Knowledge-Based System for Lean Six Sigma Implementation in Healthcare Environment

**Sub-title:** The Development of a Hybrid Knowledge-Based (KB)/Gauging Absence of Pre-Requisites (GAP)/Analytical Hierarchy Process (AHP) Model for Implementing Lean Six Sigma System in Healthcare Environment

**Keywords**: **Keywords:** Quality Management in Healthcare Environment (QMHE)**,** Knowledge Based System (KBS), Lean Six Sigma (L6σ), Gauge Absence Pre-requisites (GAP), Analytical Hierarchy Process (AHP).

To improve their services and maintain patients' satisfaction, healthcare organisations have adopted and applied different quality tools and models in recent times, with some even developing their own quality-based initiatives. For example, the approach of Lean Six Sigma (L6σ) has recently been gradually and slowly implemented in healthcare institutions. However, the nature and complexity of healthcare environment which directly impact on humans require leaders to carefully apply appropriate Quality Management (QM) systems suitable for this critical environment.

The aim of this research project is to develop a Knowledge Based System (KBS) to assist healthcare managers and practitioners during decision-making process in the context of achieving excellent benchmark and action plans prioritisation. The system will be built based on a conceptual framework for Quality Management in Healthcare Environment (QMHE) which will be modified into a model. The KBS will be developed from this model with the integration of Gauging Absence of Pre-requisite (GAP) method for benchmarking and Analytical Hierarchy Process (AHP) method for prioritisation.

The contribution of this research is the use of KBS with GAP and AHP to develop an integrated Knowledge-Based Lean Six Sigma (KB-L6σ) in QMHE. This will accomplish the necessities of investigating quality problems and recommend suitable solutions according to international best practices. It will use a systematic approach that can be applied multiple times, follow defined steps to secure consistency in the approach and integrate different healthcare management levels to maintain strategic decision-making alignment. It consists of 964 KB rules that have been produced via a knowledge acquisition process from the literature and interviewing experts in the field of QM and L6σ in healthcare environment.

Feedback from conferences and system testing were used for the verification of the model, whilst validation was carried out through three case studies implementation at three tertiary hospitals in Oman. The analysis of using the KB system in these hospitals has shown clearly that the developed system is a consistent and reliable methodology for assisting decision-makers in designing, planning, and implementing L6σ for QMHE.

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| | |
|---|---|
| **6σ** | Six Sigma |
| **ACI** | Accreditation Canada International |
| **AM** | Application Manager |
| **AHP** | Analytical Hierarchy Process |
| **AHRQ** | Agency for Healthcare Research and Quality |
| **AI** | Artificial Intelligence |
| **BB** | Black Belt |
| **BPs** | Bad Points |
| **CEO** | Chief Executive Officer |
| **$C_p$** | Capability ratio |
| **$C_{pk}$** | Process Capability index |
| **CR** | Consistency Ratio |
| **DP** | Deming Application Prize |
| **EFQM** | European Foundation for Quality Management |
| **ES** | Expert System |
| **ESDLC** | Expert System Development Life Cycle |
| **FBS** | Frame-Based System |
| **FL** | Fuzzy Logic |
| **FMEA** | Failure Mode and Effect Analysis |
| **GA** | Genetic Algorithm |
| **GAP** | Gauge Absence Pre-requisites |
| **GPs** | Good Points |
| **HAIs** | Healthcare Associated Infections |
| **IDEF0** | Icam DEFinition for Function Modeling |
| **IQ** | Intelligence Quotient |
| **ISO** | International Standards Organisation |
| **JCI** | Joint Commission International |
| **KB** | Knowledge-Based |

| | |
|---|---|
| **KBL6σ** | Knowledge-Based Lean Six Sigma |
| **KB L6σ-QMHE** | Knowledge-Based Lean Six Sigma for Quality Management in Healthcare Environment |
| **KBS** | Knowledge-Based System |
| **KH** | Khoula Hospital |
| **KPIs** | Key Performance Indicators |
| **L6σ** | Lean Six Sigma |
| **MBB** | Master Black Belt |
| **MoH** | Ministry of Health |
| **NHS** | National Health Service |
| **PCs** | Problem Categories |
| **QM** | Quality Management |
| **QMHE** | Quality Management in Healthcare Environment |
| **RH** | Royal Hospital |
| **RQPS** | Report of Quality and Patient Safety |
| **RTC** | Releasing Time to Care |
| **SQUH** | Sultan Qaboos University Hospital |
| **TQM** | Total Quality Management |
| **WHO** | World Health Organisation |
| **WIP** | Work-in-Process |

# List of Publications related to this thesis

**Journal Papers:**

1. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "Assessing Quality management System at a tertiary hospital in Oman using a hybrid Knowledge-Based System" *International Journal of Engineering Business Management*, Sage.

2. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "Knowledge-Based Lean Six Sigma System for Enhancing Quality Management Performance in Healthcare Environment" *International Journal of Lean Six Sigma*, Emerald.

3. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "The Design of a Knowledge-based System for Quality Management in Healthcare: Case Study" *International Journal of Advanced Operations Management*, Inderscience **(Accepted).**

4. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "Evaluating Healthcare Quality Management systems using hybrid Knowledge-Based System" *International Journal of Quality and Reliability Management*, Emerald **(Accepted).**

**Conference Papers:**

1. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "Developing a Knowledge-Based Lean Six Sigma Model to Increase the Effectiveness of Healthcare Organisational Resources Management" *The Second European Conference on Industrial Engineering and Operations Management*, Paris.

2. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "Evaluation of Lean Six Sigma Implementation at Healthcare Sectors: A case Study of Two Tertiary Hospitals in Oman" *The Second European Conference on Industrial Engineering and Operations Management*, Paris.

3. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "Evaluating Healthcare Governance using Knowledge-based System to Enhance Quality Management" *Proceedings of the World Congress on Engineering*, London.

4. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2018), "Developing a Knowledge-Based Lean Six Sigma Model to Improve Healthcare Leadership Performance" *Proceedings of 26th International Software Quality Management Conference*, London, 26th March 2018.

5. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2017), "New Methodology for Improving Quality Management in Healthcare Environment using a Hybrid Knowledge-Based System" *Proceedings of the World Congress on Engineering*, London, Vol. 2, pp. 692-696.

6. Al Khamisi, Y. N., M. K. Khan, and E. M. Hernandez. (2017), "A conceptual model for a hybrid knowledge-based system for quality management at healthcare environment" *The International Conference on Industrial Engineering and Operations Management*, Rabat, pp. 22-34.

# Chapter 1: Introduction

## 1.1 Background

In fact, healthcare systems have been under accumulative pressure to advance performance by controlling healthcare costs, ensuring high-quality services and better access to care (Chilingerian and Sherman, 2011). Integrated health systems are commonly considered to deliver trustable services in terms of quality and patient safety as a result of effective communication and standardised protocols within hospitals (Gillies et al., 2006).

Although, the QM aims and tools are very comprehensive, some organisations fail while trying to implement a successful QM program (Mi Dahlgaard-Park et al., 2006). According to Nwabueze (2001), there is a potential contradiction as well as complementary aspects between Total Quality Management (TQM) and employee involvement. From educational process perspective, employee involvement is inherent in TQM ideas and how it relates to the job.

L6σ, as a quality improvement tool, can be defined as 'a business strategy and methodology that increases process performance resulting in enhanced customer satisfaction and improved bottom line results' (Snee, 2010). Actually, it is consisting of Lean thinking and Six Sigma (6σ) concepts integration. This integration aims to target each and every opportunity for improvement in particular organisation and attempts to provide empowerment even at the higher-level process analysis stages (Pepper and Spedding, 2010).

According to Sharma (2003), 6σ should be used to aid and support the implementation of Lean in the organisation. When an organisation plans to construct a new framework for L6σ, this framework should be strategic and process focused,

balanced between the two philosophies, balanced between complexity and sustainability, and structured around the type of problem experienced (Pepper and Spedding, 2010).

## 1.2 Problem Statement

In similar way that different business organisations have been concerned with improving quality of service and becoming more efficient and effective in the use of resources in order to be more competitive and achieve long-term success, healthcare organisations have also understood the importance of quality improvement. Quality in healthcare is concerned with the service provided to patients, safety, performance of internal operations, healthcare procedures and the supply chain. In the last four decades, healthcare organisations have attempted to implement different initiatives to improve their quality performance, such as TQM, 6σ and Lean Thinking, with different levels of success.

All across disciplines and levels, and throughout the world, healthcare is becoming more complex (Plsek and Greenhalgh, 2001). Despite that, the healthcare industry is considered to be slow in adopting new quality improvement practices compared to manufacturing industries, although, anecdotal evidence suggests they are now being gradually implemented throughout hospitals on an increasing basis (Langabeer et al., 2009). Worldwide, the cost of medical care is increasing at an alarming and unsustainable rate. Admittedly, a significant percentage of this cost increases can be attributed to an aging population and technological advances (Koning et al., 2006).

The United Kingdom's National Health Service (NHS) is the largest healthcare system in the world. Its annual budget in 2012/13 was around £108.9 billion and it employs more than 1.7 million people (Asefeso, 2014). Unfortunately, almost £400 million is being paid in clinical negligence claims, and adverse incidents caused nearly £2 billion per year (UK, 2001). As a result of that, NHS has implemented a number of

quality improvement concepts, most recently 6σ and Lean (Proudlove et al., 2008). From their experience, the NHS decided to combine 6σ with Lean methods. This combined approach is gaining credence in manufacturing and service sectors globally (Asefeso, 2014).

In the USA, Brown and Patterson (2001) raised a major controversy in a well-known report, '*To Err is Human'*. The report recognised healthcare error as a major public health subject leading to the death of at least 44,000 and perhaps as many as 98,000 Americans each year in the US hospitals. Moreover, the National Committee of Quality Assurance estimates that up to 81,000 deaths and $3.6 billion had been paid as a result of preventable hospitalisation. This could be avoided if the healthcare system execute at the level of top most accountability (Feng and Manuel, 2008). To overcome these challenges, different QM techniques were implemented. For example, 6σ was gradually and slowly implemented in healthcare institutions starting from the year 2000 (Black and Revere, 2006).

In Oman (where the proposed KBS will be validated), the Oman's Health vision 2050 report highlighted a number of challenges for enhancing and developing research in its healthcare which will be reflected on the QMHE. These challenges are insufficient funds, lack of research prioritisation alongside national plans, poor coordination between MoH and other healthcare organisations within Oman. Other challenges include poor communication of research results, limited implementation of research, insufficient follow up of the outcomes, and poor research culture among healthcare providers.

Another challenge to QMHE in Oman is the absence of national accreditation body for healthcare organisations in the country because adopting an international accreditation system may not achieve the desires and main concern of the needs. It is, therefore, important to locally design a national accreditation system that is accredited by an

international accreditation body. Such step will help in prioritising needs and minimising cost of maintaining and upgrading systems (Oman-MoH, 2016b).

The Report of Quality and Patient Safety (RQPS): Health Vision 2050 (2016b) summarised the challenges of healthcare quality in Oman, which are: establishing computerising monitoring tool, ensuring commitment of decision-makers at all levels, establishing well-defined organisational chart that reflect the scope, building culture of quality and patient safety, and assigning budget for quality and patient safety initiatives.

Consequently, it is quite necessary to further develop an optimised method that could help QM of the healthcare organisations in reducing cost while providing high quality of services and enhancing patient safety. The proposed method will be using a systematic approach that can be applied several times, following defined steps to secure consistency in the approach and integrating different healthcare management levels to maintain strategic decision-making alignment.

Moreover, it will allow embedding expertise from reviewing international healthcare standards, latest literature publications, and interviewing healthcare QM experts and L6σ Master Black Belts (MBB) to support decision-making process. The knowledge obtained from the mentioned sources will be used as a benchmark to assess the QM in the healthcare environment. Furthermore, the approach will allow prioritising improvement for all the benchmarked actions. The developed methodology can be applied to multiple sizes of healthcare organisations, in different countries, with different organisational cultures.

### 1.3 Aim of the Research

The aim of this research is to develop a Knowledge Based System (KBS) to assist healthcare quality managers and practitioners during decision-making in order to achieve excellent benchmark and optimise solutions. This KBS will be developed by integrating

GAP and AHP methods as decision-making tool. GAP method will help in benchmarking the healthcare QM activities with the best practise, and then AHP will help to prioritise improvement for all the benchmarked actions. Additionally, the research is intended to understand and analyse the healthcare industry, acquire the critical knowledge, and recommend the appropriate action agendas to be taken for the future improvement of the KB L6σ-QMHE.

### 1.4 Objectives of the Research

The above aim can be accomplished through the following objectives:

*a)* To develop the conceptual framework (L6σ for QMHE integrated into GAP and AHP) based on the literature review and discussion with leading experts.

*b)* To transform the conceptual framework into a KB L6σ model of QMHE, arranged in a decision level hierarchy in which the KPIs are identified for each level.

*c)* To convert the KB L6σ-QMHE model into a hybrid system using the identified KPIs to create KB rules.

*d)* To develop the KB rules of QMHE. These KB rules will be placed in the ES shell and then integrated into GAP and AHP methodologies.

*e)* To verify, validate, and refine the hybrid KB L6σ system of QMHE. The verification will be piloted through determination of knowledge accurateness for input and output data along with testing justifications and compatibility with regulations (Khan and Wibisono, 2008). After the framework's development from reviewing literatures, it will be verified in a conference paper (Al Khamisi, 2017a). The feedback from verification will be used to refine and improve it accordingly. Consequently, the framework will be transformed to be a model where the KPIs will be identified and recognised. Another verification will be done to examine the interaction of the modules in the model by presenting it in a another referred conference (Al Khamisi,

2017b). Further improvement and modifications will be done to refine the model. Moreover, the model will be discussed with healthcare QM experts and L6σ MBB individually for more refinement.

The validation process will be conducted through three case studies at healthcare environment in Oman in order to enhance conformance of the KB system with experts' expectations and users' satisfaction. The feedback from this validation will be used to refine and improve the KB application.

*f)* To produce publications and obtain feedbacks that will help in verifying and improving the hybrid KB L6σ system of QMHE.

### 1.5 Research Contribution

The significance of this research is to design a new model to develop a hybrid KB L6σ with GAP and AHP system for QMHE (KB L6σ-QMHE). This approach will help in detecting issues affecting quality of healthcare systems and overcome their challenges. The originality of this research is the use of these two (GAP and AHP) methodologies in QMHE. They are essentially required to optimise the solutions obtained for decision-making. It will also suggest primary and secondary solutions based on experts' opinions and functional priorities. This method can be applied to multiple sizes of healthcare organisations, in different countries, with different organisational cultures. In recent past, hybrid KBS with GAP and AHP has been implemented in other areas, such as the ISO 9000 Advisory tool (Khan, 1999), performance measurement system (Khan and Wibisono, 2008), Lean manufacturing (Nawawi et al., 2008), low-volume automotive (Mohamed, 2013), maintenance and operation strategies (Milana et al., 2014) and Maintenance System for Sustainable Buildings (Aldairi, 2015).

From literature, there is no universally established model developed for the healthcare system. Approaches and strategies for healthcare system integration are found

where researchers have linked a number of philosophies with successful integration processes and models. These philosophies were independent of type of integration model, healthcare context or patient population served (Suter et al., 2009).

Implementing KB L6σ-QMHE in the healthcare environment will accomplish the necessities of investigating quality problems and recommend suitable solutions according to international best practices. The proposed system will benchmark the current position with the standard framework resulting from extensive evaluation of international quality concepts that can fit in the healthcare organisations, which will be concluded by recommending some solutions to seal the identified gaps. Thus, the research will provide an active decision support system that will support top management, quality managers, and practitioners in the healthcare organisations to arrange and monitor their performance and enhance their productivity as a result.

### 1.6 Research Methodology

The primary aim of any research is to review the existing knowledge, investigate current problems and provide solutions for them (Collis and Hussey, 2013). Applied researches are designed from the start to implement their findings to a precise context. In fact, research can be either *Quantitative* which concentrates on measuring the scale, range and frequency of a phenomenon, or *Qualitative* which examines and reflects on less touchable aspects of a research subject like values, attitudes and perceptions. Quantitative methodology uses several methods such as; surveys, experimental studies, longitudinal studies, and cross-sectional studies. On the other hand, Qualitative methodology uses case studies, action research, participant observation, and participative Enquiry.

The approach of this research is a mixture of literature review with knowledge acquired from experts and relative documents (international healthcare standards),

followed by development of the initial framework design followed by its transformation into a model of a hybrid KB L6σ-QMHE and further development of the system. The verification process was conducted throughout the KB design and development stages. On the other hand, the validation process is performed for the overall system through real healthcare industrial cases.

### *1.6.1 Research Road Map*

A flowchart shown in Figure 1.1 is designed starting with a comprehensive literature review and analysis of knowledge taught from multidisciplinary fields related to TQM, L6σ, QMHE and AI.

*In the methodology part,* the proposed conceptual framework, which is converted into a model, is designed. The transformed model is arranged in a decision level hierarchy in which the KPIs are considered. After that, knowledge acquisition sessions are conducted with experts in the field of L6σ and QMHE. The obtained knowledge is represented in KB rules format. These rules help in designing the hybrid KB L6σ-QMHE system that integrates with GAP for benchmarking and AHP for prioritisation.

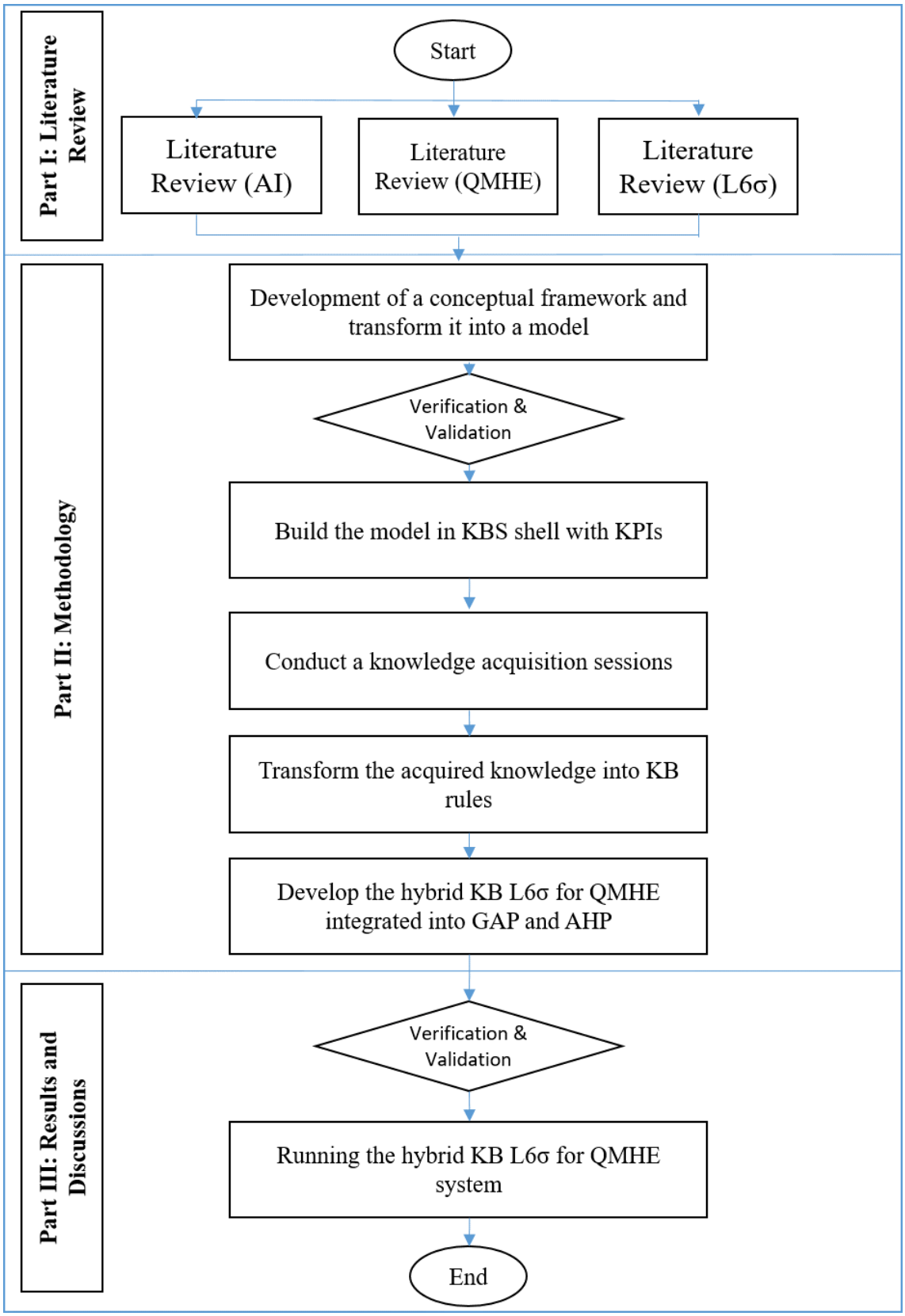


*Figure 1.1 Research road map*

*In the results and discussion part,* the KB L6σ-QMHE system is verified and validated through publishing conference and journal papers. Moreover, the validation is carried out on three tertiary hospitals in Oman in order to enhance conformance of the KB system with experts' expectations and user satisfaction. Figure 1.2 summarises the verification and validation processes of the KB system.

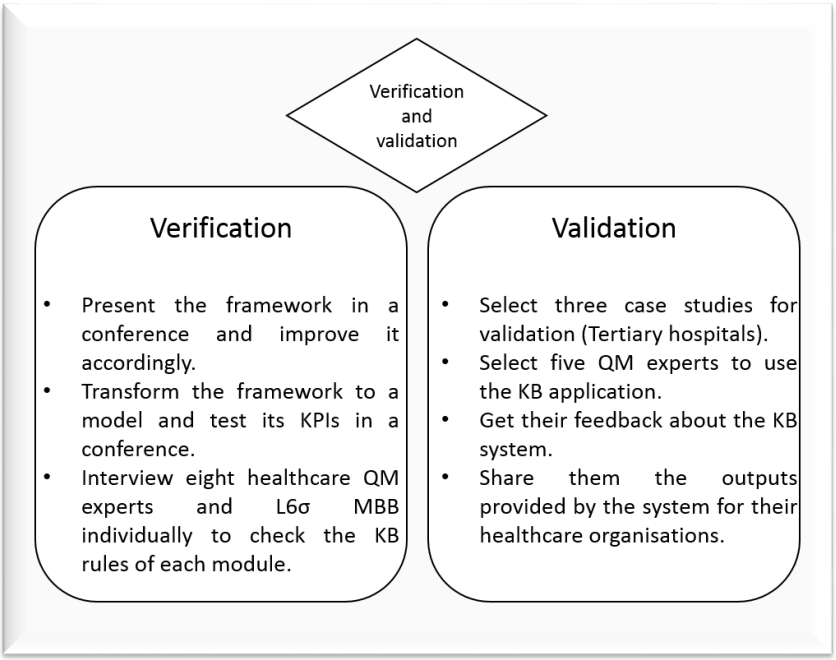


*Figure 1.2 Summary of verification and validation process*

### *1.6.2 Conceptual Development*

As earlier stated, the proposed KB L6σ-QMHE will be developed starting with knowledge acquisition, that is, collation of information via interview for enhancement of the KBS. The verification and validation will be carried out in two ways: initially, knowledge acquisition from literature review, interviews and conferences to develop the conceptual framework; and finally for the implementation of the overall system in real hospitals.

## 1.7 Thesis Outline

This thesis consists of six chapters. Chapter 1 contains the background of the research, statement of the research problem, the project aim, the research objectives, the research contribution, and the research approach.

Chapter 2 presents the literature review of the Lean, TQM, 6σ, L6σ and AI. It explains the history of QM in general and QMHE in particular. It elaborates on several applications of Lean, TQM, 6σ and L6σ in manufacturing and healthcare environment. It also explains AI techniques that are applied in a variety of applications to solve different types of problems, based on each problem field's complexity and uncertainty. This chapter also presents the detailed discussion on KBS components and structure.

Chapter 3 proposes the model of the integrated L6σ for QMHE. It starts by presenting the design framework of the system that describes planning, designing, and implementation stages. This is followed by the development of the model, the structure of the KB L6σ-QMHE system, and the design method of the hybrid KB/GAP/AHP L6σ-QMHE system. The chapter concludes with the discussion of reviewing GAP and AHP methodologies and their applications in other domains.

Chapter 4 describes in detail the development of the KB L6σ-QMHE system. In the strategic decision phase, *Level 0: Healthcare Organisation's Environment*, *Level 1: Healthcare Governance* and *Level 2: Healthcare Leadership*. While in the operational decision phase, *Level 3: Healthcare Organisation's Resources*, and *Level 4: L6σ for QMHE*. Both phases cover the key aspects of the KB L6σ-QMHE development.

Chapter 5 demonstrates the details of the validation process of the KB L6σ-QMHE. It contains the discussed results of the validation conducted in three tertiary hospitals. It also elaborates on the results of GAP analysis and AHP to draw a road map that could help the quality managers in the healthcare organisations where the system is validated.

Finally, Chapter 6 concludes this research by highlighting the achievements according to the research objectives. It discusses the research contribution to knowledge, lists the limitations of the KB L6σ-QMHE, and proposes some recommendations for future research.

### 1.8 Chapter Summary

This chapter discusses the research background, its contribution and methodology. It contains explanation of the full overview of the aim and objectives of the research, the significance and novelty of the proposed approach. Moreover, the chapter discusses the road map, conceptual framework flowchart and thesis outline. Research methodologies that will support the structure of the system proposed by this research were included and discussed as well.

# Chapter 2: Literature Review on Quality Management (QM), Lean Six Sigma (L6σ) and Knowledge-Based System (KBS)

## 2.1 Introduction

This chapter covers the research literature review in the fields of TQM, L6σ, QMHE and Artificial Intelligence (AI) concepts and methodologies. It discusses and reviews QM history and QM history in healthcare organisations. It also discusses different tools of quality improvements starting from Lean, followed by TQM, then 6σ and L6σ. Each tool is followed by its applied examples in healthcare sectors. Furthermore, it studies the mechanism of L6σ starting from initiation to evaluation. Thereafter, the differences and similarities between the Lean, TQM and 6σ are discussed. In addition, it illustrates the challenges of QM in healthcare.

The second part of this chapter covers AI techniques that are applied in a variety of ways to solve different types of problems, based on each problem field's complexity and uncertainty. Since this research will be using KBS, the components of KBS will be discussed in more details. The chapter also covers the knowledge acquisition and building methods of KBS, along with knowledge representation, and benefits and limitations of KBS. Finally, examples of AI's applications in healthcare will be discussed and explained.

## 2.2 History of Quality Management (QM)

Different tools and models around the globe are used to assess and monitor quality of products and services. A method called Lean thinking emerged within Japanese automobile industries after world war II by Taiichi Ohno and associates (Pepper and

Spedding, 2010). According to Lummus et al. (2006) Lean manufacturing concentrates on waste elimination to reach competitiveness.

After that, Deming (1986), In his book *Out of the crisis,* introduced fourteen points of management. He emphasised that the goal of quality should be to improve overall productivity, and the key to this is to understand the nature of variation and having operational objectives. Thereafter, Juran discussed new concepts of quality in his book *Juran on leadership for quality* such as: quality improvement, quality planning, quality control (Juran, 2003).

Furthermore, Ishikawa brought new concept called *fish bone diagram* which was widely used as a quality tool to organise causes of variation in the outcome of the work (Best and Neuhauser, 2008). Then, Feigenbaum devised the concept of Total Quality Control, which later became known as TQM in 1980s.

In 1987, the reliability engineer Bill Smith who was working for *Motorola Company* introduced another quality concept called Six Sigma (6σ) method (Lindsay, 2005). It aims to reduce defect rate to 3.4 defects for every million opportunities (Brady and Allen, 2006). It was the 1990s that saw the real start of 6σ when Jack Welch, CEO of *General Electric Company*, implemented the concept in the company (Welch and Byrne, 2003).

The integration of Lean and 6σ happened in the late 1990s and early 2000s (George, 2003). This integration aimed to target each and every opportunity for improvement in particular organisation and attempted to provide empowerment even at the higher- level process analysis stages (Pepper and Spedding, 2010).

Actually, Del Mar Alonso-Almeida and Fuentes-Frías (2012) listed 39 international quality awards and excellence quality models around the world. Bohoris (1995) compared *Deming Application Prize (DP) , European Foundation for Quality*

*Management (EFQM)* (Dijkstra, 1997, Bou-Llusar et al., 2009, Eszter Tóth and Jónás, 2012) and *Malcolm Baldrige Criteria for Performance Excellence* (Mathan and Yeung, 2015, Flynn and Saladin, 2006). He found that the DP focuses on the dissemination of companywide quality control, continuous improvement and relations with suppliers.

The Malcolm Baldrige Criteria for Performance Excellence accepts that quality is customer-driven and therefore focuses on customer satisfaction, benchmarking, and competitive comparisons with the industry average, the industry leader, and the principal competitors in the company's key markets. The EFQM focuses on the relations with the community, and customers' and employees' satisfaction (Bohoris, 1995). Oakland (2014) in his book *Oakland on Quality Management* and in *Total Quality Management and Operational Excellence: text with cases* developed a new model based on all the excellent work done in the previous models.

### *2.2.1 History of QM in Healthcare*

QM in healthcare has used different tools to monitor and control its services. From the literature, all the new QM tools are initiated by business and manufacturing sectors and then used by healthcare organisations (Black and Revere, 2006, Langabeer et al., 2009, Vest and Gamm, 2009). In the UK, the NHS has implemented a number of quality improvement concepts, most notably 6σ and, more recently, Lean (Proudlove et al., 2008). Moreover, since the inception of TQM, healthcare organisations have adopted and applied different quality tools and models with some even developing their own quality-based initiatives. Matthias and Brown (2016) summarised eight key NHS quality initiatives starting from the first attempt to standardise clinical audit as part of professional healthcare in 1989 and ending by transforming urgent and emergency care services in England in 2015.

The most popular quality movement in the USA and many other countries is 6σ (Black and Revere, 2006). It was gradually and slowly implemented in healthcare institutions in the year 2000 (Black and Revere, 2006). Although, the principle of 6σ can be found in the quality pioneers' writings like Deming since 1980s, Revere et al. (2004) claimed that 6σ emerged from the fertile environment created by the TQM movement in US healthcare organisations in which there was high need for significant, continuous improvement in the outcomes of quality of patient care, processes, and services. Some operational inefficiencies are because of the direct healthcare service delivery process where as others are associated with administrative and operational healthcare system (Koning et al., 2006).

In next few sections, researcher will discuss the main QM methods in details. This discussion will include; Lean, TQM, 6σ and L6σ.

### 2.3 Lean Thinking

In fact, there is no agreement on a definition of Lean production among the researchers (Pettersen, 2009). In general, it is a waste elimination tool to reach competitiveness. It can be defined as *a way to specify value, line up value-creating actions in the best sequence, conduct those activities without interruption whenever someone requests them, and perform them more and more effectively* (Womack and Jones, 2003). Lean aims to change culture, increase commitment and enhance 4-Ps – *philosophy* of adding value to consumers and society; *processes* paying off over time; *people* who are appreciated and developed; and *problem-solving* to continue organisational learning (Liker and Meier, 2006).

Moreover, it helps to reduce work lead times, remove all practices of waste, reduce set-up times, and map the value stream. It seeks to prevent sub-optimisation by concentrating on the whole value chain. Consequently, it is weak on organisational

infrastructure, deployment plans, analytical tools, and control (Koning et al., 2006). Anvari et al. (2011) listed the main elements that help in the elimination of these waste activities, they are: excess production, excess processing, delays, transport, inventory, defects and movement. Womack and Jones (2003) summarised key principles of Lean thinking as: identify the value wanted by the consumer and value stream for each product, make the product run non-stop, introduce pull between all steps, aim for perfection so that the number of steps and the amount of time and information needed to attend to the consumer continually decreases.

Asefeso (2014) summarised the main criticisms of Lean thinking as lack of consideration for human factors, lack of strategic perspective and inability to cope with variability. He added that Lean is more suitable for manufacturing process design.

### *2.3.1 Lean in Healthcare*

The term *Lean Healthcare* is concentrating on efficiency and patient satisfaction by defining clearly the value added procedures, and it is considered to be quite new (Brandao de Souza, 2009). Obviously, healthcare institutions adopted values of Lean system from manufacturing (Vest and Gamm, 2009). Much of the attention is focused specifically on work processes, quality, and efficiency. Implementation of Lean in healthcare and the broader public sector are often studied (Radnor et al., 2006). Laursen et al. (2003) stated that Lean started in the 1940s but it was launched in the healthcare system in 2002. The diagram in Figure 2.1 shows the history of Lean.

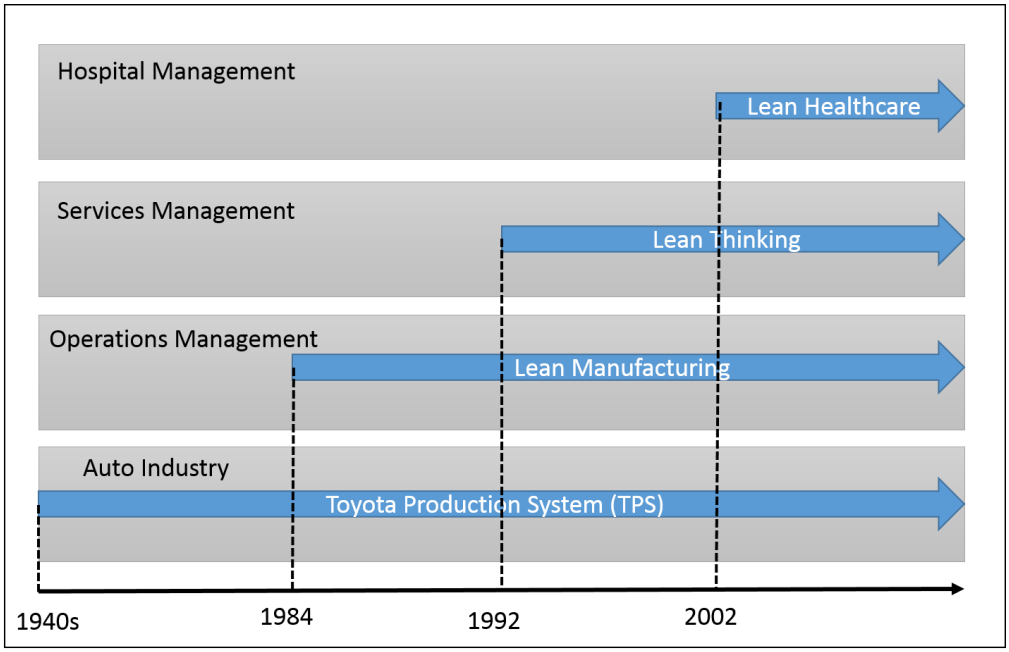


*Figure 2.1 Lean healthcare development, modified from Laursen et al. (2003)*

Bridges (2006) proposed that Lean can be used not only to sleek waste from the healthcare environment, but as a method of producing real motivations for innovation and value creation. Al-Balushi et al. (2014) have found seven important categories of readiness factors of a successful launch of Lean in healthcare which are: strong leadership support, initiating Lean with the strategic program, understanding what value and customer groups be present in healthcare. Furthermore, undertaking the end-to-end process view, staff training and participation in Lean principles and methods, measurement and reward systems aligned to Lean objectives, and equivalent demand and capacity levels to increase flow.

In fact, few hospitals around the world are implementing Lean at the whole organisation level such as; Virginia Mason Medical Centre in USA (Bohmer and Ferlins, 2006), Flinders Medical Centre in Australia (Ben-Tovim et al., 2007) and Royal Bolton Hospital NHS Foundation Trust in the UK (Fillingham, 2007). At operational level example, Lean was introduced by Lummus et al. (2006) when they implemented Lean in a physician's clinic and the results showed that the capacity of that office has increased

without adding people or equipment, lower waiting times for people with scheduled appointments, increase the opportunity for patients without appointments to be seen at the last minute, and lower the stress levels for the clinic's staff.

In the UK, Bolton Hospital, with the help of an external consultancy, has taken its first tentative steps in 2005 towards becoming the first Lean hospital in the UK. The implementation of Lean in this hospital decreased the paperwork by 42%, reduced the total length of stay by 30% and declined the mortality rate by 38% (Fillingham, 2007). However, Matthias and Brown (2016) emphasised that significant operational and cultural obstacles must be overcome for the full strategic benefits of Lean in NHS. They added that more holistic approach in providing a full service for the whole of the patient journey is needed. In fact, Lean has launched a programme called Release Time to Care (RTC), which was designed to utilise Lean improvement techniques, the intrinsic motivators of social movement theory and the front line engagement theories of large-scale change in a healthcare environment (Waring and Bishop, 2010).

The Swedish healthcare has established a measurement system for following up lead-times in order to deal with long waiting times and delays (Kollberg et al., 2006). They have added that the first step in applying Lean thinking in healthcare is to put the patient in the center and include time and comfort as key performance measures of the system. After proper analysis of the challenges of an operating theatre, Lean methodology introduced new admissions' process with the consideration of simple principles such as: pre-operative preparation must be done for each and every patient, anaesthesiologists must be informed about the case one day before and the patient must be at operation theatre no later than 7:35 am.

The first discussing on Lean in healthcare in Oman was in the 1st International Conference on Quality Management in Healthcare at Sultan Qaboos University, Sultanate

of Oman. It was introduced by Buheji (2007). More examples of Lean application in healthcare organisations can be seen in; Kim et al. (2006), Joosten et al. (2009) and Al Farsi et al. (2014). In a systematic literature review about Lean interventions in healthcare, Moraros et al. (2016) emphasized that Lean interventions have no statistically significant association with patient satisfaction and health outcomes. They found, also, a negative association between Lean interventions with financial costs and worker satisfaction. Moreover, they said that, the benefits on process outcomes of Lean intervention like patient flow and safety are inconsistent.

### 2.4 Total Quality Management (TQM)

According to Martínez-Lorente et al., (1998), TQM started to be known in the mid 1980's and only became a considered part of the quality-related language in the late 1980's. In fact, Feigenbaum and Ishikawa are perhaps the greatest contributors to the development of the TQM's term. According to Koller (1991), Dean and Bowen (1994), Martínez-Lorente et al.(1998), and Prajogo and Sohal (2003), TQM came as a result of global competition between companies especially in manufacturing in Western countries to attract customers and gain profit. This narrow customer focus, as a result, may build an oppression of the serviced market in which companies see the world only through their current customers' eyes (Prajogo and Sohal, 2003).

This discussion went further to consider TQM as one of the most competitive weapons between companies (Beskese and Cebeci, 2001). Although, TQM as a concept and application was established and applied by private sectors (Kluse, 2009) because of companies' desire to invest great efforts to ensure high satisfaction of their customers and thus ensure their loyalty (Dakic, 2010), but it can be seen in many governmental successful applications around the world in the previous years (Kluse, 2009).

Basically, several authors defined TQM with some differences (Sitkin et al. (1994), Hackman and Wageman (1995) and Dale et al. (2007). Wruck and Jensen (1994) defined TQM as 'a science-based, non-hierarchical, and non-market-oriented organising technology that increases efficiency and quality'. According to Eriksson and Garvare (2005), TQM is a constantly growing management system containing values, methodologies and tools, the purpose of which is to rise external and internal customer satisfaction with reduced amount of resources.

Chang (2009) said that the fundamental ideas of TQM set forth by Deming, Juran, and Ishikawa gained significant acceptance and has become something of a social movement. Moreover, TQM philosophy pressures a systematic, joined, constant, organisation-wide view including everyone and everything, and concentrates mainly on total satisfaction for both the internal and external customers within a management environment that search for continuous enhancement of all systems and processes (Ho, 2015).

The core concepts of TQM can be classified into two broad categories or dimensions: social or soft TQM, and technical or hard TQM (Yong and Wilkinson, 2001, Lewis et al., 2006, Dotchin and Oakland, 1994, Bou-Llusar et al., 2009, Calvo-Mora et al., 2013). According to Bou-Llusar et al. (2009), the social issues are centred on human resource management and emphasize leadership, teamwork, training, and employee involvement. The technical issues reflect an orientation toward improving production methods and operations and seek to establish a working method through the establishment of well-defined processes and procedures to make possible the constant improvement of goods and services to customers.

### *2.4.1 Implementation of TQM in Healthcare*

Healthcare management is no stranger to transformational efforts like TQM and process re-engineering (Bigelow and Arndt, 2000). 'TQM has become something of a social movement and it has spread from its industrial origins to healthcare organisations, public bureaucracies, non-profit organisations and educational institutions' (Hackman and Wageman, 1995). Rao (2015) emphasized that although TQM has wide applicability in healthcare and is extensively researched, there is no consensus on the definition of TQM in healthcare.

In fact, implementation of TQM variables has shown positive relationship with hospitals' performance (Alolayyan et al., 2011, Ali and Alolayyan, 2013, Sweis et al., 2013). However, most NHS managers in the UK are not interested in TQM as a tool for improving their organisational performance and enhancing patient care. They believe that TQM has failed to address the critical needs of hospitals especially on issues such as enhancing performance, efficiency and effectiveness (Nwabueze, 2016). According to Mohammad Mosadeghrad (2014), the failure of TQM implementation could be because of non-holistic approach adopted in its implementation, managers inadequate knowledge of TQM implementation and frequent top management turnover.

## 2.5 Six Sigma (6σ)

6σ refers to a statistical measure of defect rate in a system. Sigma (σ, also called a Standard Deviation) is a measure that is used to calculate the amount of variation of a set of data values from a mean of the samples (following a Normal Distribution). Magnusson et al. (2003) defined 6σ as 'a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in

ways that minimize waste and resources while increasing customer satisfaction by some of its proponents'. It can be defined as a powerful strategy developed to accelerate improvement in quality of product, process and service, by relentlessly focusing on reducing variation and eliminating waste (Antony and Coronado, 2001). It is deployed by carrying out improvement projects that are selected based on a translation of the company strategy into operational goals (Pyzdek, 2004).

According to Mi Dahlgaard-Park et al. (2006), DMAIC process is considered to be a major improvement methodology in 6σ. It is consisting of five phases (Define, Measure, Analyse, Improve, and Control). Figure 2.2 shows that out of a total of services provided by a particular organisation, 99.7300 % fall within the desired quality range for +/-3 Sigma. If the organisation applies 6σ, its quality range of service will reach 99.9999998%.

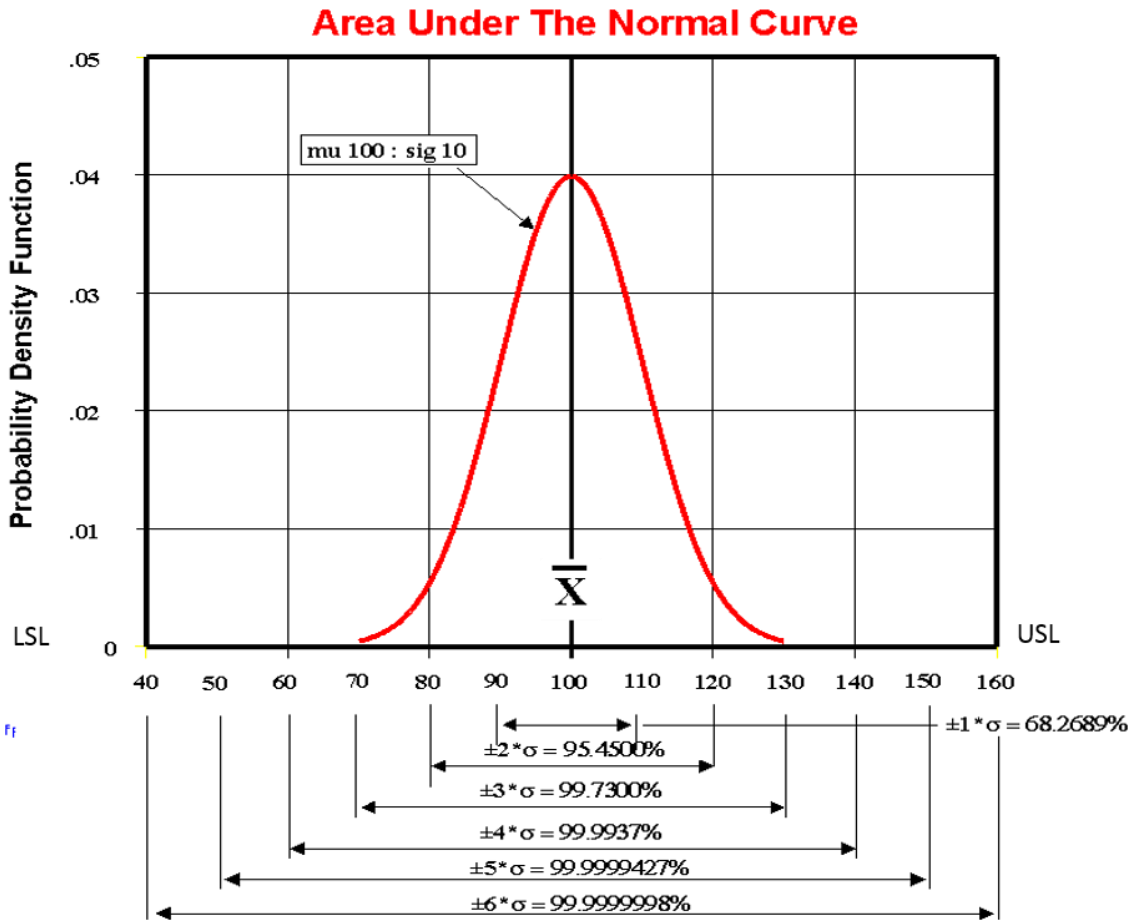


*Figure 2.2 Six Sigma approach*

A Software is used to analyse collected data that automatically shows the state of the process in the control charts and calculating process capability indices: Process Capability ratio ($C_p$) and Process Capability index ($C_{pk}$). $C_p$ estimates what the process is capable of servicing or producing if the process mean were to be centred between the specification limits. If $C_p<1$, then the process does not meet specifications. $C_{pk}$ estimates what the process is capable of servicing or producing, considering that the process mean may not be centred between the specification limits. If $C_p>1$ and $C_{pk}>1$, then the process meets specifications. If the process is "under control", the computing capability index does not make sense. In Figure 2.2, the $C_p$ and $C_{pk}$ can be identified by the following equations:

$$C_p = \left(\frac{Upper\ spicification - Lower\ spicification}{6\sigma}\right) = \left(\frac{160-40}{6\times 10}\right) = 2$$

$$C_{pk} = Min\left(\frac{mean\ - Lower\ spicification}{3\sigma}\ ;\ \frac{Upper\ spicification - \ mean}{3\sigma}\right)$$

$$C_{pk} = Min\left(\frac{100\ - 40}{3x10}\ ;\ \frac{160 - \ 100}{3x10}\right) = Min\ \left(\frac{60}{30}\ ;\ \frac{60}{30}\right) = Min\ (2{:}\ 2)$$

The DMAIC process has been discussed widely with 6σ. This process can be explained as: *Define* which process or product that needs improvement, *Measure* data that help set priorities and criteria, *Analyse* carefully required measurements, *Improve* result of analysis accordingly and *Control* if the implementation was successful and make sure that improvement is continuous over time (Lin et al., 2013).

One of the most important elements in 6σ is a significant belts training for the organisation's employees by very experienced MBB. This training can be categorised at three belts: Black Belt (BB), where the employees spend weeks learning 6σ techniques/philosophies. The other two belts are yellow and green belts, where the employees in a 6σ organisation attend at least minimal training (Schroeder et al., 2004). This training make very durable improvement assembly similar to the management ladder in an organisation and this is the key strong point and differentiator of 6σ (Proudlove et al., 2008).

### *2.5.1 Implementation of Six Sigma (6σ) in Healthcare*

The application of 6σ in healthcare services is fairly new and very little research has been carried out (Tolga Taner et al., 2007). In the previous twenty years, healthcare organisations such as Baxter Health and Mount Carmel Hospital have shown success through 6σ implementation (Koning et al., 2006). In 2001, 6σ was used in medication delivery processes at Froedtert Hospital, USA. The results showed that by implementing 6σ methodology, a significant variability in the ordering and processing of Intra-venous

drips was identified. In these areas, standards were created by a multidisciplinary task force to reduce variation (Buck, 2001).

6σ methodology has shown significant results by reducing patients' fall rates in an Academic Medical Centre of King Fahd Hospital in Saudi Arabia. The rate decreased dramatically from 6.57 to 1.91 which is more than 70% reduction (Kuwaiti and Subbarayalu, 2017). There are several examples of 6σ application in healthcare, which include; decreasing turnaround time between general surgery cases (Adams et al., 2004), improving processes and outcomes in hospitals (De la Lama et al., 2013), improving microbiology laboratory processes (Elder, 2008), and reducing incidence of catheter-related bloodstream infections in a surgical intensive care unit (Frankel et al., 2005).

Despite the above successful implementation of 6σ, Asefeso (2014) summarised the main criticisms as; inconsideration for interaction, independency of processes improvement and requirement of significant infrastructure. He added that 6σ is over detailed and complicated for some tasks. Antony et al. (2018) found in their systematic review that 6σ applications in healthcare have been focused on the entire hospital with no real focus on a particular department or function.

### 2.6 Lean Six Sigma (L6σ)

As mentioned earlier, the integration of Lean and 6σ happened in the late 1990s and early 2000s (George, 2003). Despite that, L6σ had started to rise pointedly since the new millennium particularly after the 2004-2007 period (Muraliraj et al., 2017). In fact, separate concepts of Lean and 6σ are greatly researched compared to the integrated concept. The integrated Lean and 6σ aims to target each and every opportunity for improvement in a particular organisation and attempts to provide

empowerment even at the higher-level process analysis stages (Pepper and Spedding, 2010).

According to Snee (2010), *L6σ* can be defined as 'a business strategy and methodology that increases process performance resulting in enhanced customer satisfaction and improved bottom line results'. It is a business improvement methodology that aims to maximise shareholders' value by improving quality, speed, customer satisfaction, and costs: it achieves this by merging tools and principles from both Lean and 6σ (Laureani and Antony, 2011). When an organisation plans to construct a new framework for L6σ, this framework should be strategic and process focused, balanced between the two philosophies, balanced between complexity and sustainability, and structured around the type of problem experienced (Pepper and Spedding, 2010).

In fact, L6σ aims to delight the organisation's customers by delivering higher quality service in less time. Hence, to achieve the aim of L6σ, it is important for an organisation to improve its process by eliminating defects and focus on how the work flowed through the process as shown in Figure 2.3.

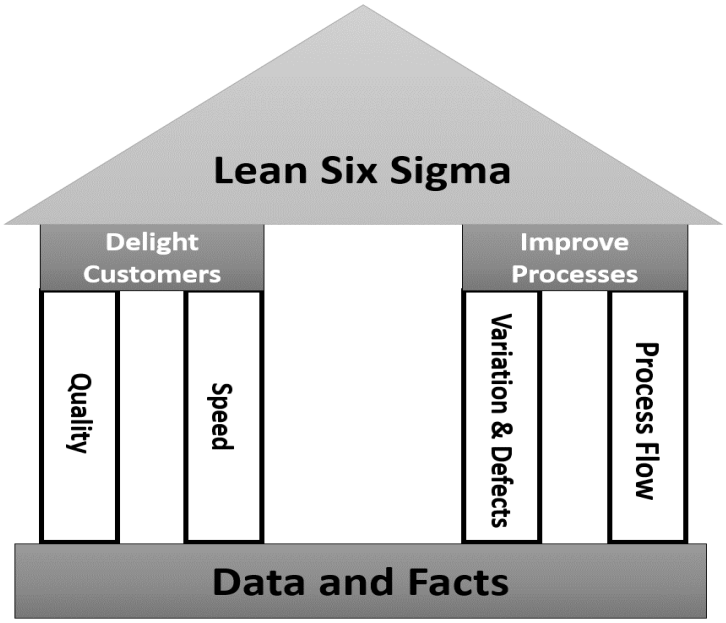


*Figure 2.3 Keys to L6σ, adopted from (George et al., 2007)*

Antony (2006) has summarised the benefits of L6σ from the literature in both manufacturing and service organisations as; ensuring services or products conform to what the customer needs, removing non-value adding steps (waste) in business processes, reducing cost of poor quality, reducing the incidence of defective products or transactions, shortening the cycle time and delivering the correct product or service at the right time in the right place. Pepper and Spedding (2010) concluded that, if Lean is applied without 6σ, then there is a lack of tools to force improvement to its full potential and if 6σ is implemented without Lean thinking, then there would be a lack of tools for the continuing improvement. Hence, the union of Lean and 6σ improvement methods is necessary to facilitate the reduction of the cost of complexity (George, 2003).

The implementation strategy in this research is built on extensive investigation of DMAIC key success and failure factors. This implies that, DMAIC cycle is a screen type approach in which the project or issue must be tested against some main conditions to decide whether it can be structured to meet the DMAIC criteria. It is more likely to have a successful and sustainable process improvement by joining L6σ implementation with the concept of realistic evaluation that considers individual as well as environmental characteristics (Black, 2009). To summarise, Lean, 6σ, and L6σ are not for the faint-hearted. They need hard work, self-reflection, the willingness to learn, and the willingness to change (Bliss, 2009).

### *2.6.1 Mechanism of Lean Six Sigma (L6σ)*

Since this research is depending on L6σ principles, it is very important to understand the pre-requirements, deployment and evaluation of these principles. Morgan and Brenig-Jones (2015) presented a completed picture about the deployment of L6σ

starting from identifying customers and understanding their needs. Thereafter, it is important to determine the chain of events by identifying the value in a steam map. The next step is to precisely assess the present performance and identify ways to improve them. The collected data should be presented using a control chart to identify upper and lower control limits.

According to George (2003), the deployment of L6σ in service organisations is divided into 4 phases. The first is *readiness assessment*, conducted through selecting champion for the L6σ project and establishing a baseline snapshot. The second is *engagement*, by involving people in the organisation to remove reasons for them to actively resist L6σ projects. The third is *mobilisation*, where an executive team and infrastructure will be created, training will be scheduled and the first wave of projects will be selected. The fourth phase of deployment is to *control* the performance by planning ahead what will happen when results show, and how the organisation can do the same work with less time.

After the deployment process is completed, the next stage is the improvement process using DMAIC as discussed earlier. George et al. (2007) defined the DMAIC process as doing specific activities in a specific sequence followed by gathering data in nearly every phase and concluded by making sure the solutions really will eliminate the cause of the problem to fix. Figure 2.4 shows the typical time line for L6σ implementation starting from initiation and ending by evaluation.

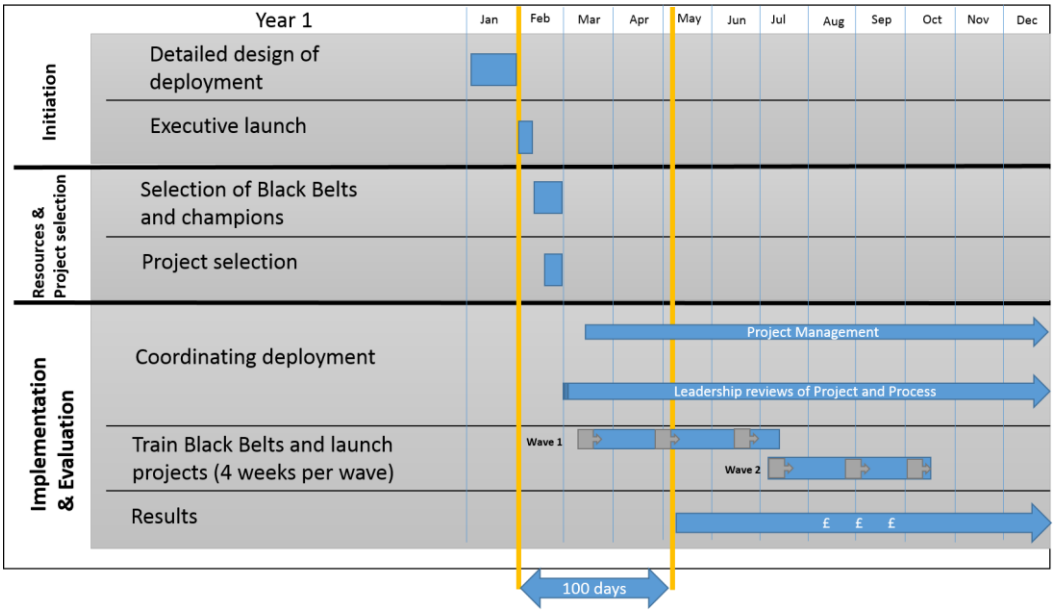


*Figure 2.4 Time line for L6σ implementation, adopted from (George et al., 2007)*

### *2.6.2 Implementation of Lean Six Sigma (L6σ) in Healthcare*

In fact, healthcare organisations have been slow to adopt L6σ, although anecdotal evidence suggests that they are now being gradually diffused throughout hospitals on an increasing basis (Langabeer et al., 2009). An example of this diffusion can be seen in Mayo Clinic Rochester in the USA. In 2011, the use of Lean and 6σ approaches in this organisation has increased operation theatre efficiency and financial performance. The operation room efficiency was enhanced by process mapping, top management support, staff involvement, and sharing performance metrics (Cima et al., 2011). Kuo et al., (2011) examined L6σ application in post anaesthesia care unit workflow. They found that L6σ in healthcare model closed the service gaps between healthcare workers and patients, balanced the needs of healthcare managers, and provided healthcare services to patients by combining the Lean speed and 6σ high-quality principles.

The Red Cross Hospital in the Netherlands was certified by ISO in 2000 and started to apply 6σ in 2002. Although 6σ (with ISO) worked well in different projects at this hospital, it failed to resolve some of them like reducing length of stay in chronic

obstructive pulmonary disease patients, allowing parents to stay within their children's room and decreasing the number of mistakes in invoices (Koning et al., 2006). As a result of that, the hospital applied Lean management to solve three problems: reducing hiring of personnel, decreasing operating theatre opening times and maintenance. The integration of Lean management with the 6σ concept showed significant results.

Another example can be seen in Netherlands, as well, in the University Medical centre. This organisation has used the process-focused method of L6σ to reduce hospital stay by facilitating the discharge procedure and eliminating waste and waiting time. The results showed that the average length of stay of trauma patients was reduced from 10.4 days to 8.5 days (Niemeijer et al., 2010).

In Floyd Medical Centre community hospital, USA, L6σ has been implemented via a 100 day trials (Faulkner, 2009). The implementation led to sustainable results and a marked change in culture. Moreover, there has been a revolution in the way leaders look at problems. They seek to reduce variation in their business and work processes. They were interested in getting baseline data. Averages alone were no longer acceptable, they should include standard deviation and a control chart. A minimum of 30 data points was needed. There was the willingness to wait to get the best data possible before making a key decision. Changes were tested on a smaller scale before full implementation (Faulkner, 2009).

Another example of L6σ approach implementation can be seen in joint replacement surgical procedures at the Richard L. Roudebush Veterans Affairs Medical Centre, Indiana (Gayed et al., 2013). Surgical operation processes for patients undergoing total joint replacement were redesigned to fulfil the L6σ requirements. A multidisciplinary team including the orthopaedic surgeons, frontline staff, and executive management identified waste in the current processes and initiated changes to reduce waste and

increase efficiency. The results showed that the length of stay decreased 36% overall, decreasing from 5.3 days during the pre-project period to 3.4 days during the 20-month sustainment period. Moreover, the returns of the centre has increased by $1 million annually compared with baseline cost and volumes (Gayed et al., 2013).

A common factor affecting hospitals' capability to improve their processes related to their ability to streamline patient flow. According to Arthur (2011), although the average patient turnaround in an emergency department exceeded four hours but New Jersey hospital reduced it, through application of L6σ tools, to 38 and 90 minutes for discharged and admitted patients respectively.

L6σ has been implemented, also, in a University Hospital in Italy from January 2013 till December 2014 in the general surgery department to reduce the risk of Healthcare Associated Infections (HAIs). Analysing data of more than 20,000 patients who underwent a wide range of surgical procedures has shown a significant decrease in both the number of hospitalisation days and the number of patients affected by HAIs (Montella et al., 2017). Mason et al. (2015) reviewed the using of L6σ systematically and they found that it has the potential to produce clinically significant improvement for surgical patients.

Notwithstanding the above implementation examples and more others ( Agarwal et al., 2016, Montella et al., 2017, Chaurasia et al., 2017), L6σ approach is hard to be evaluated, given that the lack of difficult estimation or obviously sustained enhancements offers little evidence supporting broad adoption (Glasgow et al., 2010) Resistance due to lack of understanding of L6σ and a lack of belief that it will work, and lack of roadmaps to follow are the most critical challenges that face L6σ implementation (Snee, 2010).

## 2.7 Discussion about Lean, TQM and 6σ

Although, the QM aims and methodologies are very comprehensive, the failures of organisations trying to implement a successful QM program have been well noted (Mi Dahlgaard-Park et al., 2006). According to Nwabueze (2001), there is a potential contradiction as well as complementarities between TQM and employee involvement. This involvement is inherent in TQM ideas in terms of an educational process and more direct involvement in quality and how it relates to the job. He added, there is a noticeable level of mystery about TQM in real practice; while it encourages involvement, there is an active assertiveness on encouraging management control and monitoring. This control and monitoring leads to reduction of the employees' performance due to a perception (or reality) of management taking unfair advantage. The implementation of TQM is another challenge leading to low performance and satisfaction according to many researchers.

Nwabueze (2001) emphasized that one of the most important element in TQM success is organisational culture which till now is ambiguous in terms of culture change and cultural transformation. Cao et al. (2000) suggest that TQM application needs to be restricted to those contexts where processes dominate. Black and Revere (2006) highlighted three new concepts that were not available in TQM: time and money deliverables, the 6σ metric, and quality customer focus. As shown in Figure 2.5, they explained that with TQM, quality improvement was open-ended and open-financed and was a never-ending effort with few identifiable results. While TQM made constancy of purpose and continuous improvement forever for the product or service, 6σ establishes deliverable quality improvement in a specific time frame (Simmons, 2002).

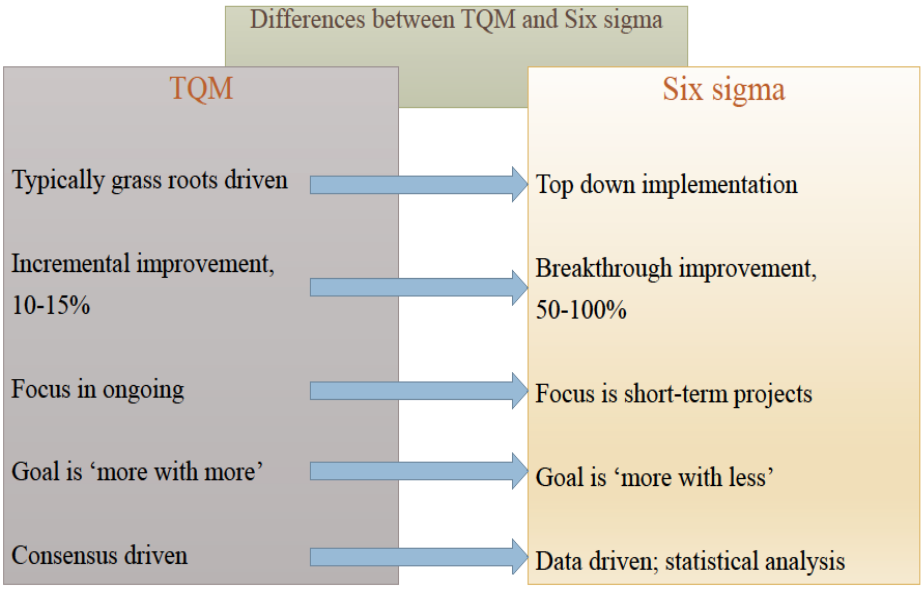


*Figure 2.5 Differences between TQM and 6σ, modified from Black and Revere (2006)*

Furthermore, 6σ teams use measurements as result to analyse problems and improve the customer satisfaction. This measurements cannot be seen clearly in TQM. They concluded that 6σ teams work only on things that are important to the customers not like TQM which is focusing on all process, outcomes and services that could be perceived by the patient.

To conclude, although, there are many reasons behind the failure of TQM implementation such as: un-clear goals, insufficient planning, poor management commitment, insufficient training, ambiguous framework, lack of resources, and absence of effective measurement, the most important reasons are organisational culture and leadership/management commitment. on the other hand, Klefsjö et al. (2001) argue that 6σ concept did not bring anything new and considered it to be as a methodology within the larger framework of TQM. The only new concept brought by 6σ is reducing variation and improving processes which gave an accurate results and improved customer satisfaction (Klefsjö et al., 2001).

Anvari et al. (2011) noted two main differences between Lean and other improvement methods: First, Lean focuses on improving entire value streams where as others focus on individual processes. The second difference is that Lean is aiming to eliminate non value adding activities which are known as waste. Lean and TQM have many similarities in general but they differ significantly at the operational level (Pettersen, 2009). Other authors criticise the Lean concept as disposing to the impact of changes, reducing flexibility and difficult to response to new conditions and circumstances (Dove, 1999). As illustrated in Figure 2.6, Lean thinking and 6σ have gone through parallel development and both of them are now used in administration and services besides manufacturing (Koning et al., 2006). Finally, 6σ and Lean are excellent road-maps, which could be used one by one or combined, together with the values in TQM (Andersson et al., 2006).

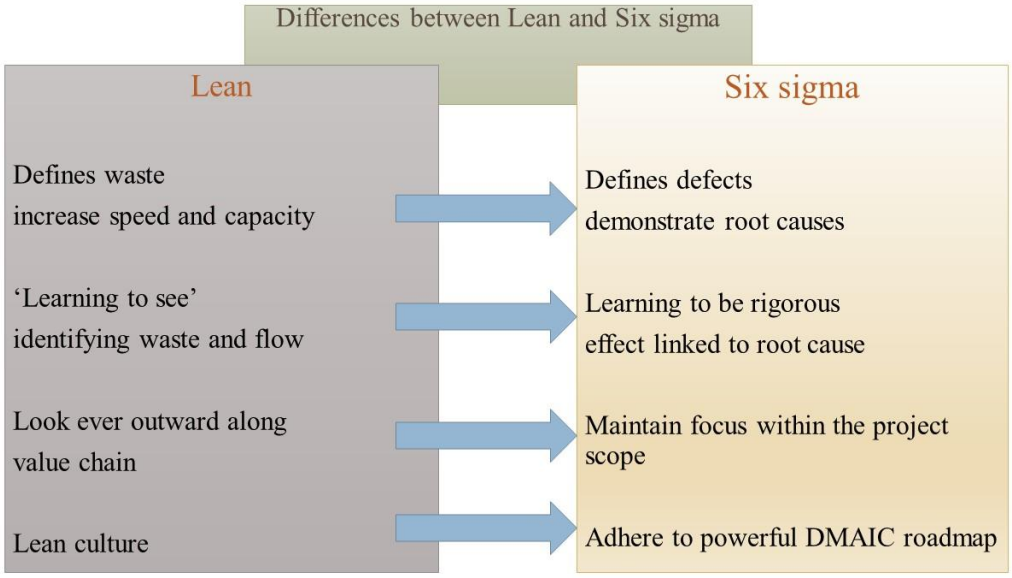


*Figure 2.6 Differences between Lean and Six Sigma, adapted from (Proudlove et al., 2008)*

### 2.8 Challenges of QM in Healthcare

The cost of medical care is increasing at an alarming and unsustainable rate worldwide. Admittedly, a significant percentage of these cost increases can be attributed to an aging population and technological advances (Koning et al., 2006). Basically, there is no agreement among reserachers to define QMHE. Harteloh (2003) discussed how difficult it was to standadrise a definition for quality in healthcare. The Institute of Medicine in the USA defines quality of care as 'the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge' (Lohr, 1990). Worldwide, the patient's satisfaction has been used widely to measure the quality of services provided in healthcare facilities. The Agency for Healthcare Research and Quality (AHRQ) define QMHE as *doing the right thing for the right patient, at the right time, in the right way to achieve the best possible results* (NCQA., 2016).

Campbell et al. (2000) created their definition of quality of care based on two dimensions: accessibility and effectiveness. They defined it as the 'ability of the patient to access effective care with the aim of maximising health benefit in relation to need'. Healthcare systems have been under accumulative pressure to advance performance by controlling healthcare costs and ensuring high-quality services and better access to care at the same time (Chilingerian and Sherman, 2011). For example, the challenge in the Lebanese healthcare organisations is how to achieve equilibrium between quality and accessibility to the healthcare (Sabry, 2014). If a healthcare system is not working to improve health, there would be no reason for it (WHO, 2000).

Schouten et al. (2008) concluded their systematic review that using different quality improvement collaborative to accelerate the improvement and satisfy the patients play a key part, but may have a little effect on the outcomes in terms of the basic

components and cost effectiveness. From different QM initiatives used in healthcare, accreditation has been progressively considered as the ideal method to promote healthcare QM (Grimshaw et al., 2012). In fact, delivering a safe care for patients depends on several factors; clinical governance, efficient communication, teamwork, risk assessment, inter-professional education and effective leadership (Corkin 2017).

According to Irfan and Ijaz (2011) the high level of patients' expectations about the quality of service had pressured the healthcare service providers to detect the key factors that are essential to raise healthcare services that improve patients' satisfaction and decrease time and money involved in managing patients' complaints. Brown and Patterson (2001) raised a major controversy in the famous report, *To Err is Human*. The report recognised healthcare error as a major public health subject leading to the death of at least 44,000 and perhaps as many as 98,000 Americans each year in US hospitals. McGlynn et al. (2003) found that patients in the USA received only 55% of the recommended care.

The NHS in the UK distributed a report in 2000 detecting the important effect of adverse events in the NHS (Vincent et al., 2001, Baker and Norton, 2002). Integrated health systems are commonly considered to run trustable performance in terms of quality and patient safety as a result of effective communication and standardised protocols within hospitals (Gillies et al., 2006). They concluded that healthcare plans used in the care delivery system are related to clinical performance measures and not considered patient perceptions of care which is proposed to be considered by this project. Suter et al. (2009) recommended that the current knowledge on health systems needed to be integrated to advance effective service delivery with evidence-informed decision-making as an expectation in healthcare management and policy.

### *2.8.1 Challenges of QM in Oman's Healthcare*

Hard and serious efforts were taken since the 1970s to improve the quality of health services in Oman. In 2000, WHO ranked Oman's healthcare system as one of the best ten healthcare systems in the world, even better than the Canadian and American systems (WHO, 2000). According to WHO, from 1990 till 2013, the rate of under-five mortality in Oman decreased by 72 percent (WHO, 2015). The same report showed that Oman's general government expenditure on health of total government expenditure was 4.8% in 2012.

Al-Mandhari (2016) described the quality efforts in Oman between the year 2000 and 2014. This is when MoH recruited a QM Consultant, passing through the development of Quality Assurance Strategy in 2005 and the establishment of the Department of Quality and Patient Safety in the regional hospitals in 2007, and later culminating in the establishment of the Directorate General of the Quality Assurance Centre in 2014.

According to RQPS (2016b) the number of facilities of the quality system rose from 64 primary health centres in 2005 to 165 in 2012. The number of regional hospitals applying the system rose to 10 compared to zero in 2000, and the number of certified national auditors increased from 240 in 2005 to more than 800 in 2012. In the year 2000, staff and user satisfaction surveys started to be implemented as a tool of quality improvement at the MoH's facilities which gave results that were used to inform decision making on different aspects especially training and structural changes needs.

Furthermore, according to Oman's Health vision 2050 report (2014) the health system in Oman is now facing the load of the epidemiologic transition to non-communicable diseases which are generally related to life-style of the individuals. These diseases are increasing in the population, their control is hard using the common

community health measures, they are expensive to diagnose, manage and treat and they are generally lifetime conditions. The second burden according to the report is malnutrition and congenital anomalies. The life expectancy has risen from 72.6 years in 2001 to 76.2 years in 2015 (WHO, 2015).

The Oman's Health vision 2050 report highlighted a number of challenges for enhancing and developing health research which will be reflected in the quality of healthcare such as: insufficient funds, lack of research prioritisation with the national plans, poor coordination between MoH and other healthcare organisations within Oman, poor communication of research results, limited research topics are implemented, insufficient follow up of the outcomes and poor research culture among healthcare providers.

Another challenge to Oman's healthcare QM is the absence of national accreditation body for healthcare organisations in the country because adopting an international accreditation system (whether ACI, or ISO or any other) may not achieve the desired results. Therefore, it is important to design a national accreditation system that is accredited by an international accreditation body. Such step will help in prioritising needs and minimising cost of maintaining and upgrading systems (Oman-MoH, 2016b).

In 2016, the Omani Minister of Health promulgated a decree to form a national committee that represents all healthcare organisations in Oman in order to create national guidelines for healthcare accreditation and maintain it frequently. This committee will also follow up the implementation of national standards at Omani healthcare organisations, train national auditors, issue accreditation certificates, coordinate with international accreditations bodies and create knowledge base of all national standards (Oman-MoH, 2016a).

The RQPS (2016b) summarised the challenges of quality in Oman as: establishing computerizing monitoring tool, ensuring commitment of decision makers at all levels, establishing well-defined organisational chart that reflect the scope, building culture of quality and patient safety and assigning budget for quality and patient safety initiatives.

To overcome these challenges, the use of AI, that shows a durable, constant and easy able tool in different applications, is the aim of this research. In the next few sections, a literature review in the field of AI will be given. The review will give more attention to KBS since it is the back bone of this research.

### 2.9 Artificial Intelligence (AI)

Knowledge is considered to be the heart of ES. It is the human understanding of a specialized field of interest that has been learnt through study and experience. It is also a sum total of perceptive processes that aids to draw a meaningful conclusion (Awad and Huntington, 1996), and is formed in processes that have the dimensions of space and time (Hautala and Jauhiainen, 2014).

Rasskin-Gutman (2009) explained that the nature of intelligence has been undertaken by three schools to create linked theories. The biological school, which works by correlating intelligent activities with brain functions; the psychometric school, which measures intelligence by the intelligence quotient (IQ); and the school of cognitive psychology, which defines how to trigger intelligence by the mental process. Carter (2008) was insisting that IQ test does not cover all aspects of human life performance and he added new assessment areas like an agility test and memory test. Awad and Huntington (1996) explained that intelligent behavior has several attributes like ability to understand

and use of language, ability to store and retrieve relevant experience (memory) and skills that is acquired by study (learning).

Turing's influential paper, 'Mind', is a main turning point in the history of AI (Turing, 1950). It formed concepts of programming an electronic computer to act intelligently, including an explanation of the landmark imitation game that is known as Turing's Test (Buchanan, 2005). The goal of AI as a science is to make machines think things that would need intelligence if done by humans (Boden, 1977). According to Munakata (2008), there is no standard definition of exactly what AI is. He defined AI as 'the study of making computers do things that the human needs intelligence to do'. The first book on AI programs was 'Computers and Thought' published in 1963 by Feigenbaum and Feldman (Buchanan, 2005).

### *2.9.1 Techniques of AI*

In recent years, the modern method to AI has concentrated more on bottom-up techniques where some basic building blocks of intelligence are put together and get them learn and develop over time (Warwick, 2013). In fact, different techniques can be seen in literature reviews such as; Artificial Neural Networks (ANNs) (Shepherd and Koch, 1990, Livingstone, 2008, Negnevitsky, 2011), Simulated Annealing (SA) (Koulamas et al., 1994, Munakata, 2008, Sureja and Chawda, 2012), Frame-Based System (FBS) (Minsky, 1975, Warwick, 2013) , Fuzzy Logic (FL) (Zadeh, 1965, Hayward and Davidson, 2003), Genetic Algorithms (GA) (Mitchell, 1998, Ghaheri et al., 2015) and KBS/ES. Since this research is using KBS/ES technique, further discussion about it will be carried out including its components, knowledge acquisition, knowledge

representation, its benefits and limitations, and its applications in healthcare environments.

### *2.9.2 Knowledge-Based System (KBS)*

Quinn (1990) defined an ES as 'an interactive computer program that asks the same questions a human expert would ask, and from the information given to it by the user, provides the same answer the expert would provide'. According to Khan (1999) ES and KBS as terminologies in literature are usually synonymous, however there is an indirect difference. There was a realisation that the ES was not truly reaching the knowledge, experience and wisdom of human experts and it was a misnomer to call it ES. However, since it contains a strong element of knowledge, it was later named (more accurately) as KBS. All KBS have four components (Figure 2.7): knowledge base, inference engine, scheduler and user interface (Awad and Huntington, 1996).

i. Knowledge base: contains actual knowledge in the ES acquired from the human expert. This knowledge is represented in the form of IF…THEN type rules, facts, and assumptions about the problem the system is designed to solve.

ii. Inference engine: It is the main processing element of ES which draws conclusions on the available knowledge (Giarratano and Riley, 2005). It is a group of computer programs that organise the reasoning and inferencing based on the rules of the knowledge base to come up with a solution (Awad and Huntington, 1996).

iii. Scheduler: This explains exactly how the ES arrived at the solution. This explanation works as a useful instructional aid and builds a trust between ES and users.

iv. User interface: This enables all communication between the user and the system. Without user interface, the ES becomes ‘black box’ incapable of seeking any additional information required.

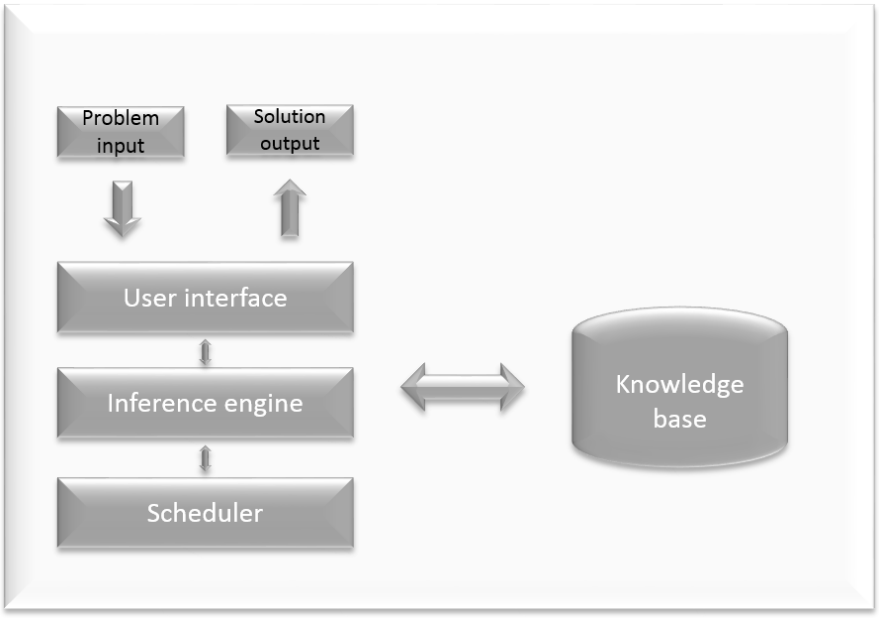


*Figure 2.7 KBS components*

The final goal of ES is to capture the experts’ experience into a single knowledge base (Chapman and Pinfold, 2001). It is the input from various sources such as human expert, research papers, and books (Benavides, 2002). Sunnapwar and Kodali (2006) emphasised that ES/KBS should be implemented carefully because it is expensive and relative investments are not reversible. Failures of ES/KBS range from selecting the wrong problem domain, chasing the wrong talent to develop the ES, poor verification and validation of the system, a lack of understanding of the expert’s knowledge, and other causes. Currently, ES/KBS is widely applied in business organisations to facilitate the

decision-making process (Udin, 2004, Nawawi, 2009, Milana et al., 2014, Aldairi, 2015) because it is a time-saving and accurate decision-making tool. It makes uncommon expertise more commonly available and provides trusted information to beginners.

#### *2.9.2.1 Knowledge Base (KB)*

It is the source of the rules, facts, and knowledge acquired from the human expert. The knowledge in this base is typically represented in the form of IF…THEN type rules, facts and assumptions about particular problem the system is developed to solve (Awad and Huntington, 1996). The knowledge base is not static; as new knowledge becomes available the knowledge base needs to be updated (Maqsood et al., 2011). The knowledge in the KB is combined with the system via a process called knowledge representation (Maqsood et al., 2011) which will be discussed later. There are two general types of rules in KB: a definitional rule and a heuristic rule. In a definitional rule, the inference engine establishes a relationship between terms.

For Example,

**IF** home state is Muscat

**THEN** home country is Oman

In a heuristic rule, there is some level of uncertainty in the answer. For example

**IF** country is UK and place of birth is Oman

**THEN** citizenship is Oman (confidence .60).

### *2.9.2.2 Inference Engine*

It is a cluster of computer programs that organises the reasoning and inferencing based on the rules of the available knowledge base to come up with a solution (Awad and Huntington, 1996). It is the brain of a ES/KBS and is also known as the control program or rule interpreter (Wibisono, 2003). The inference engine is a vital component that makes the inferencing and selects how and when the facts and rules in the knowledge base are to be used in solving the problems (Mohamed, 2013). The inference engine uses reasoning techniques in making inferences by referring to the knowledge base. It processes knowledge by either forward chaining or backward chaining, as shown in Figure 2.8. Forward Chaining is the data driven approach where the reasoning begins from the known data and continues forward with that data until it grasps a conclusion or a goal (Negnevitsky, 2011). According to Udin (2004), Milana et al. (2014) and Aldairi (2015), in forward chaining, the ES/KBS is analysing and examining the input using IF condition in the IF-THEN rule. It gathers information and then infers from it whatever can be inferred. In backward chaining, it searches backward for the facts that will achieve the known goal.

Initial Facts: A, B, C, D, E, F, G, H, I

Rules

**Rule 1**: **IF** A and B **THEN** F

**Rule 2**: **IF** C and D **THEN** G

**Rule 3**: **IF** F and G **THEN** H

**Rule 4**: **IF** E and H **THEN** I

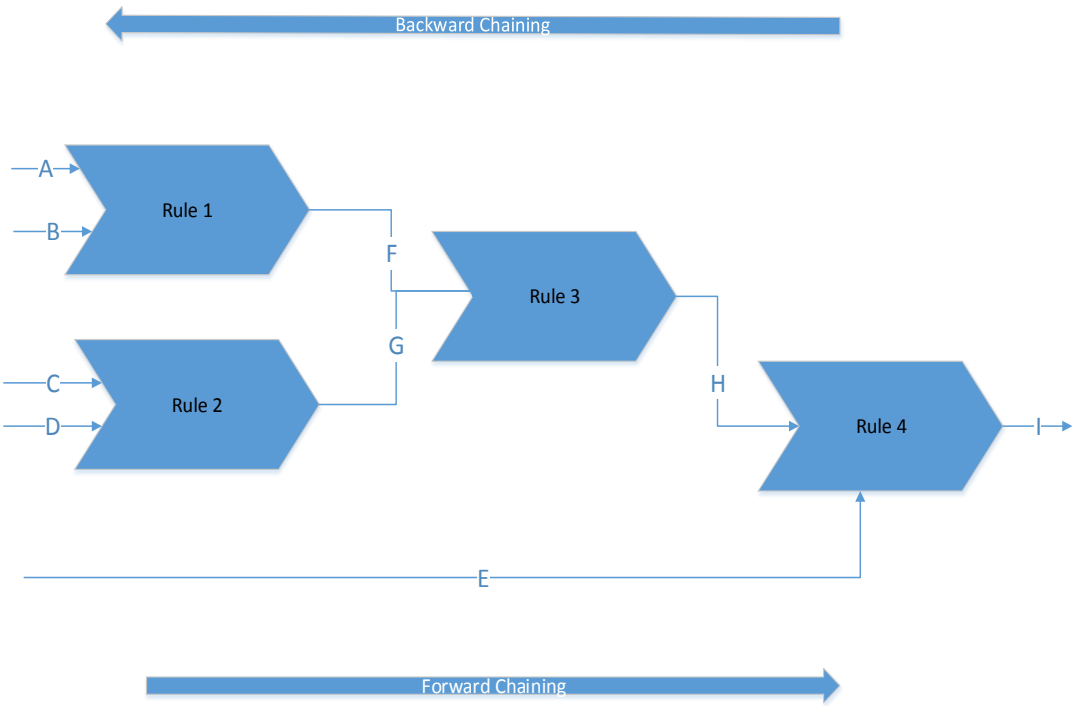


*Figure 2.8 Forward chaining and Backward chaining approaches, modified from (Mohamed, 2013).*

Since A and B are known facts, F can be known by Rule 1 and since C and D are known facts, G can be known by Rule 2. Knowing F and G will lead to knowing H using Rule 3. The same is applicable in the chain till the system arrives at the solution in (I). Backward chaining will start from (I) as the solution. To know (I), the user needs to know E and H by using Rule 4 and to know H, user needs to know F and G using Rule 3.

The following are some real examples of backward chaining:

Rules

1. IF wake up at 5:30

   THEN pack at 6:00

2. IF pack at 6:00

THEN leave home by 6:15

3. IF leave home by 6:15

   THEN park car by 6:30

4. IF park car by 6:30

   THEN sign at register 6:45

5. IF sign at register 6:45

   THEN start your job at office at 7:00 **(KNOWN GOAL)**

In fact, forward chaining is data-driven while backward is decision or goal-driven as can be seen in Figure 2.9. Forward chaining aims for any conclusions while backward aims for a particular data. Forward chaining is more suitable for diagnosing while backward chaining is useful for scheduling and monitoring (Negnevitsky, 2011).

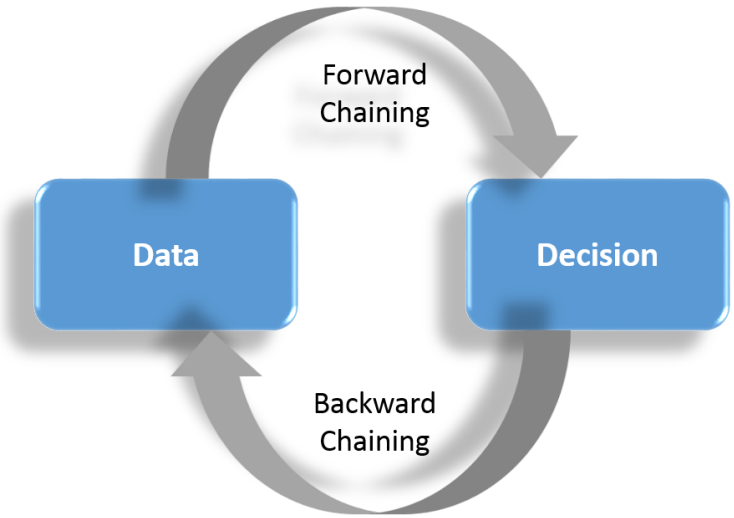


*Figure 2.9 Forward and backword chaining starting points*

#### *2.9.2.3 Blackboard*

Awad and Huntington (1996) defined blackboard as a shared database in which various knowledge sources work together to solve a problem. In simple language, it is a collection of experts' experiences to solve a particular problem. Blackboard is similar to the computer hardware idea of Random Access Memory (RAM). It works as a global storage for the input data, variables, and the final solution (Chau and Albermani, 2005).

#### *2.9.2.4 Human involvement in KBS*

According to Mohamed (2013) there are two types of human involvements in KBS: end user, who uses the system looking for a solution to certain problem and the human involved in the knowledge acquisition process. This process needs the involvement of a knowledge engineer and the expert. The person who seeks and then builds the knowledge from the experts of the particular area through interviews to find out how a particular problem can be solved is called a knowledge engineer (Khan and Wibisono, 2008). On the other hand, the domain expert is a knowledgeable and skilled person who has deep knowledge, experience, skills and judgement in solving problems in a particular domain, and is providing the skills on how to solve the problem that the ES/KBS will execute.

#### *2.9.2.5 Uncertainty*

Hopgood (2011) emphasised that uncertainty in building rules for the KBS could be caused because of three reasons; uncertain evidence, uncertain links between evidence and the conclusion, or vague rule. The uncertain evidence and uncertain links are recommended to be handled by Bayesian updating, while vague rule must be solved through fuzzy logic (Aldairi et al., 2017). To overcome uncertainty in the KB rules, this research will not use any of the above techniques, but it will use *Explanation facility* which contains clear

description of the key rules with additional knowledge as it will be shown in Section 3.5.2 and Figure 4.3.

#### *2.9.2.6 Knowledge acquisition*

This refers to the process of acquiring, processing, understanding, and recalling information using one of different methods that will be discussed in this section. Awad and Huntington (1996) defined it as a process of arresting expert's thought and experiences. They added that knowledge acquisition is a demanding process in which a knowledge engineer cooperates with the expert to transform expertise into coded program by elicit information from the expert, interpreting the information and build rules that represent the expert's solutions. As a pre-requisites for knowledge acquisition, knowledge engineer must take in consideration the problem domain, selecting the right expert and preparing well for the knowledge acquisition. Table 2.1 shows the role of knowledge acquisition in different steps of the Experts System Development Life Cycle (ESDLC).

*Table 2.1 Knowledge acquisition activities in the ESDLC, adopted from (Awad and Huntington, 1996)*

| | ESDLC Step | Knowledge Acquisition Activity |
|---|---|---|
| 1 | Problem identification and feasibility determination | • Seek out a champion<br>• Locate a cooperative domain expert |
| 2 | Knowledge acquisition | • Apply appropriate tools to tap the expert's knowledge |
| 3 | Knowledge representation | • Represent the expert's heuristics via prototyping.<br>• Verify the rules with the expert |
| 4 | Verification/Validation | • Correct existing rules and add missing rules by working closely with the experts through rapid prototyping |
| 5 | Implementation | • Work with the user to ensure system acceptance and proper training |
| 6 | Maintenance | • Meet with the expert and the user to determine procedures and content with maintaining and updating the system. |

Knowledge acquisition usually starts by reviewing documents and reading books, papers and manuals related to the problem domain. After that, capturing of more knowledge can be achieved by the following different ways:

*Interviewing:*

Since knowledge is not available systematically, researchers have to conduct several sessions of interviews with experts (Appendix A) till the system is built to the satisfaction of the domain expert and the end user. The interview as a tool is used mainly in early stages of the acquisition. Validity and reliability of questions during interviews must be considered. The interview has different advantages such as: flexibility, evaluating the validity, eliciting information and many people enjoy being interviewed. It could be structured or unstructured interview. However, the interviews have their disadvantages:

communication difficulties between parties, response bias, hostile attitude or standardized questions.

*On-site observation:*

It is a process of observing, interpreting, and recording an expert's problem solving behavior while it takes place (Awad and Huntington, 1996). This methodology enables the knowledge engineer to request knowledge within the working world of the expert. The challenges of on-site (in situ) observation technique is that a knowledge engineer may spend a long time waiting for the problem to happen and, if does happen, it might not be completed at that time.

*Brainstorming:*

It is unstructured approach of gathering ideas about a particular problem. In this technique, the knowledge engineer is inviting two or more experts into a session and presenting them a problem where they will generate ideas. Brainstorming tool could be conducted electronically between multiple experts.

*The Delphi method:*

It is a survey of experts concentrating in a given problem domain. It is designed by a series of questionnaires to capture expert's opinion in solving a particular problem. Each expert's contribution will be shared with other experts to build the next questionnaire. The Delphi method has anonymous response and controlled feedback. Tsai et al. (2010) implemented this method to assess a hospital performance in quality.

To conclude, the knowledge acquisition part is not an easy task to achieve through a traditional interview process. Knowledge engineers should re-evaluate how well the experts understand the problem domain and how accurately they are modelling it. The

Knowledge engineer should elicit the expert's knowledge through concrete case situations.

#### *2.9.2.7 Knowledge representation*

It is the know-how to program knowledge through an appropriate representation scheme. It is the most critical phase in building a KBS because the representational framework is the basis for learning how information was obtained and interrupted. This representation could be done by different strategies. Firstly, semantic network, which is a collection of nodes links together to form a net where the knowledge engineer can graphically represent knowledge. Secondly, it could also be represented into frames, or thirdly, rules. Rules represent the major elements of the scheme and easy to understand and write. It also shows relationships between variables. Rules are produced in IF...THEN way, where IF is the premise and THEN is the action (Awad and Huntington, 1996). Decision tables and decision trees are considered to be other ways of knowledge representation. In this research, the proposed system will be built by production of rules.

#### *2.9.2.8 Benefits and limitations of KBS*

ES has offered new ways of sharing and distributing knowledge in fast time and reliable way. Increasing productivity and output are the most important benefits of KBS. It has a standardized approach to solve problems which works smarter in general. According to Giarratano and Riley (2005), ES increases confidence that the correct decision was made by providing a second opinion to a human expert. They added that ES can explain in details the reasoning that led to a conclusion. Furthermore, ES is considered to be steady, unemotional, and complete response at all times.

Although ES are used widely around the globe, they do have limitations as any system has (Elofson, 1995). These limitations could be in terms of high cost and less

experts and knowledge engineers availability. In some cases, management un-support for the ES because it is threatening to job security and career progression (Awad and Huntington, 1996) could be consider as its limitation.

### *2.9.3 Examples of AI's Applications in healthcare*

AI is drawing important contributions in virtually all areas of healthcare and all other businesses. The following are some examples of its applications in healthcare:

i. Diagnosing: Saha et al. (2016) developed a semi-supervised based gathering approach using the search capability of a multi-objective SA based approach. The suggested technique can handle small clusters and it can be used to identify segments having tumours in the brain. Furthermore, Gunasundari et al. (2016) applied GA to speed up bounded Boolean unit group optimisation for better feature selection in liver and kidney disease diagnosis. They proposed two new developed Boolean particle swarm optimisation algorithms called Velocity Bounded and Improved Velocity Bounded to solve feature selection problem in liver and kidney. Moreover, Ertuğrul et al. (2016) shifted one dimensional local binary patterns from gait to detect Parkinson's disease. The proposed approach may also use speech in Parkinson's disease detection. Moreover, the computational cost and memory requirement of this approach are low enough that it can be engaged in any real-time application by detecting local changes in a signal.
ii. Controlling: Bureerat and Limtragool (2008) used SA with multi-resolution design variables optimise structural topology. The study concluded that the effects of the use of multi-resolution design variables improves the

performance of the SA optimisation method. The finest results gotten from using SA are said to be comparable to those obtained from using the classical gradient-based approach. Furthermore, Charbonnier et al. (2016) used interactions between brain regions of electroencephalogram index to control operators' mental fatigue monitoring. The index measures the abnormality of the spatial covariance matrix calculated on 20 seconds from a mean spatial covariance matrix learned during an initial state of the process.

iii. Automation systems: Khader et al. (2016) proposed a data mining tool to improve pharmacy automation. They extracted knowledge from prescriptions transactional database to improve different strategies in pharmacy automation and management. The discovered knowledge, specifically, improved the planogram process. The knowledge is attained through the examination of the possible associations within the prescribed drug regime for different patients.

iv. Monitoring of clinical pathways: Huang et al. (2016) evaluated monitoring services using a real clinical dataset affecting the unstable angina clinical pathways. They presented unusual treatment event prediction and clinical outcome prediction to explain how to exploit the potential of monitoring clinical pathways from both internal and external views.

Since this research is about QMHE, the following examples of ES applications can be seen:

- Patient-focused and continues performance improvement in healthcare: Büyüközkan et al. (2011) developed a model that can assess the perceived service quality in healthcare sector in Turkish hospitals. The model was evaluated by fuzzy AHP. Data collected from hospitals used in the model to

measure the relative healthcare performance of the alternative hospitals. The results showed that hospitals should focus more on empathy, professionalism and reliability to provide satisfying and qualified services.

- Evaluating health-care waste disposal alternatives: Dursun et al. (2011) used A fuzzy multi-criteria group decision-making framework for evaluating health-care waste disposal alternatives. A fuzzy multi-criteria group decision-making framework is presented to resolve the problems met when using classical decision-making methods in evaluating healthcare waste disposal technologies. A hierarchy of evaluation criteria and their related sub-criteria is employed in order to conduct a more effective analysis.
- Relationship between healthcare professionals and knowledge management: Chen et al. (2011) identified key factors affecting infection control departments of Taiwanese hospitals to adopt knowledge management. The most important factor influencing the introduction of knowledge management is "Support from the Technology Supplier," followed by "Executives' leadership Style," and "Colleagues' Computer Literacy." On the other hand, the least important factor is "Hospital Culture," followed by "Hospital Resource Support," and "Assistance from the Information Consultant."
- Exploration of healthcare quality indicator: Chae et al. (2003) used data mining and decision support system to analyse quality indicators of healthcare. The important factors influencing the inpatient mortality were identified using a decision tree method for data mining based on 8,405 patients who were discharged during the study time. These factors were length of stay, classes of disease, discharge departments, and age groups.

## 2.10 Chapter Summary

This chapter has covered the research literature review in the fields of TQM, L6σ, QMHE and Artificial Intelligence (AI) concepts and methodologies. It has discussed and reviewed QM history in general and QM history in healthcare organisations. It has also explained different tools of quality improvements starting from Lean, followed by TQM, then 6σ and lastly, L6σ. Each tool has been followed by examples of its implementation in healthcare sectors. Furthermore, it has studied the mechanism of L6σ starting from the initiation state to the evaluation state. Thereafter, it has discussed the differences and similarities between Lean, TQM and 6σ. In addition, the challenges of QM in healthcare has been illustrated.

The second part of this chapter has covered AI techniques that are applied in a variety of ways to solve different types of problems, based on each problem field's complexity and uncertainty. Since this research will be using KBS, the components of KBS have been discussed in more details. The chapter has also covered the knowledge acquisition and building methods of KBS, along with knowledge representation, and benefits and limitations of KBS. Examples of the various applications of AI in healthcare have been discussed and explained.

Figure 2.10 summarise the research gap based on the literature review conducted in this chapter.

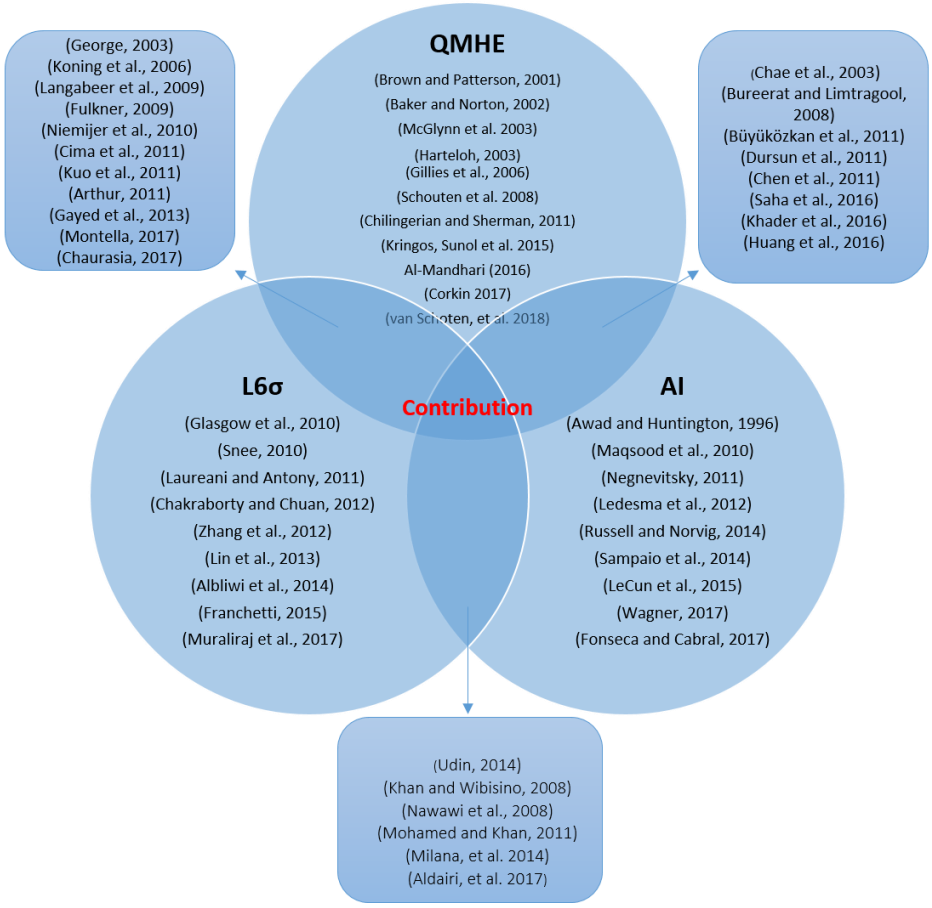


*Figure 2.10 Research gap*

At the end of this chapter, literatures review shows that no study was carried out to integrate a KB System embedded with both GAP and AHP to facilitate the implementation of L6σ in QMHE. The next chapter will show how knowledge obtained from the mentioned literature will help to build the proposed KBS.

# Chapter 3: Development of KB L6σ-QMHE Model

## 3.1 Introduction

This chapter covers the full development of the research conceptual framework and its transformation into a model. By doing that, the first and the second objectives of the research will be achieved. Therefore, the chapter defines the main practical steps representing strategic and operational phases in order to build the conceptual framework. It also explains the transformation of the conceptual framework into a hybrid KB L6σ model of QMHE that arranged in a decision level hierarchy in which the KPIs are considered. The developed framework and the transformed model have been refined and improved based on the feedback received from publishing them in five conference papers. This chapter also covers the two methodologies that will be integrated with the KBS: GAP and AHP. Finally, the *AM application* software that used for building the KBS and the *super decision* software that used for AHP calculation are explained.

## 3.2 The KB L6σ-QMHE framework development

As mentioned earlier, this research concentrates on suggesting an original framework for KB L6σ-QMHE because there is no current solid framework that addresses the issue of implementing L6σ in QMHE context. Figure 3.1 shows the systematic steps taken for the framework development.

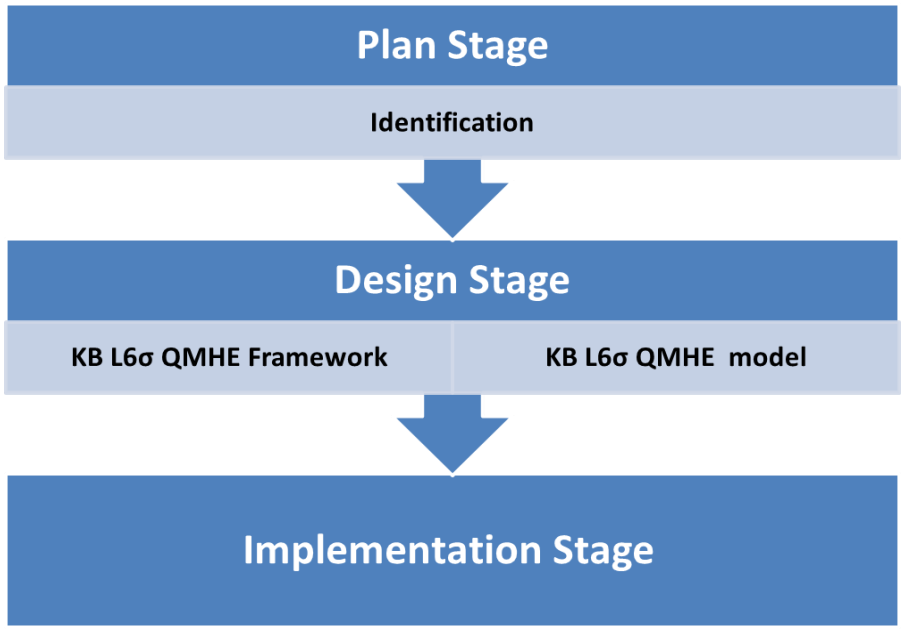


*Figure 3.1 Conceptual Framework Development Steps*

Plan is the first step in developing the framework. This start with an identification of the problem followed by the main area of this research that deals with the core assessment components of the KB L6σ-QMHE system. Then, it is necessary to look for the healthcare organisation's resources and L6σ implementation. The literature review found that failure to implement L6σ might cause a major negative impact on the healthcare organisation's resources. Thus, for the purpose of this research, and in order to have a smooth implementation, the KB L6σ-QMHE model is designed to serve three main stages: Plan, Design, and Implementation. Chapter 2 has reviewed most of the critical elements of L6σ-QMHE. The information obtained will be interpreted into a KB and will be utilised as the base of the conceptual framework.

As Figure 3.1 shows, the framework displays the **plan stage**, in which the healthcare organisation's statement is recognised and healthcare quality dimensions are assessed. Then, the phase is extended to include the *design stage*, which includes the main area of this research that deals with the core assessment components of the KB L6σ-QMHE system (governance and leadership modules). As can be seen in Figure 3.2, the

*Plan Stage* acts as the starting point from which the healthcare organisation's statement and healthcare quality dimensions must be identified. Furthermore, general information of the organisation will be addressed in order to assess strategic competencies and readiness to change into the L6σ-QMHE framework.

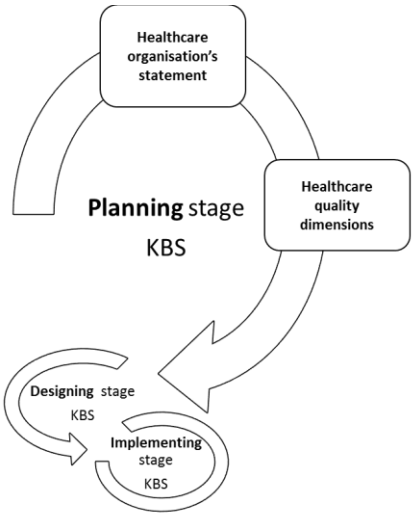


*Figure 3.2 L6σ-QMHE Framework (Plan Stage)*

This stage can be defined as a *purification chamber* that can discover whether the healthcare organisation can progress further with the implementation of L6σ or if it will be in need of major changes. The healthcare organisation has to be assessed initially through a concrete readiness evaluation. This step should be integrated in the plan stage of the L6σ of QMHE, after the determination of the organisational quality dimensions. During this stage, the examination of organisational mission, vision, and objectives must be carried out. According to Al Khamisi et al. (2017a), two modules of information need to be considered in the *Plan Stage*: *Healthcare Organisation Environment module*, and *Healthcare Quality Dimensions module*.

The **design stage** discusses the primary perspective of the healthcare organisation by assessing the current position of QM in the healthcare system at both levels; governance and leadership as Figure 3.3 shows.

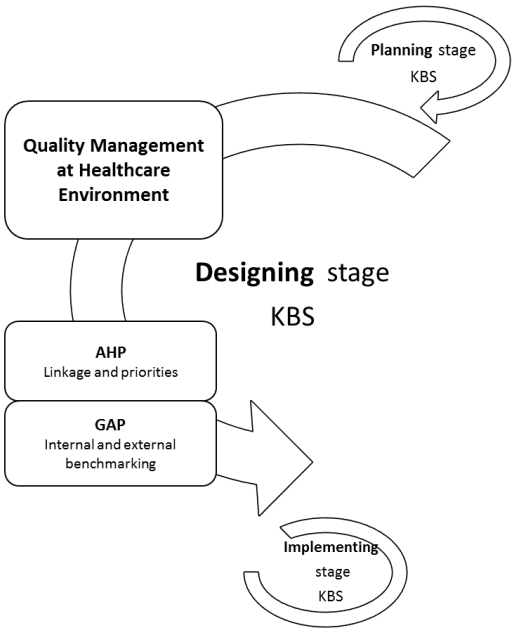


*Figure 3.3 L6σ-QMHE Framework (Design Stage)*

Also, at this stage, the framework will progress with benchmarking and prioritisation by integrating GAP and AHP techniques. The results from this stage will show how far the healthcare organisation is from the desired best practice (benchmark). This stage aims to raise the healthcare QM aspects within a healthcare organisation. The evaluation at this stage begins with governance standards and leadership standards with different healthcare accreditation bodies. The integration of L6σ in healthcare QM is a multipart process that involves a clear consideration and focus while planning to develop such KB. Thus, for L6σ, the serious path is to choose suitable KPIs that lead to a comprehensive quality assessment process for QMHE and is able to recommend best answers to QM issues in healthcare. This will be integrated within the process of producing the system KB rules.

The important part will start with the **implementation stage** where all the theoretical aspects in the previous two stages would be translated here as Figure 3.4 shows.

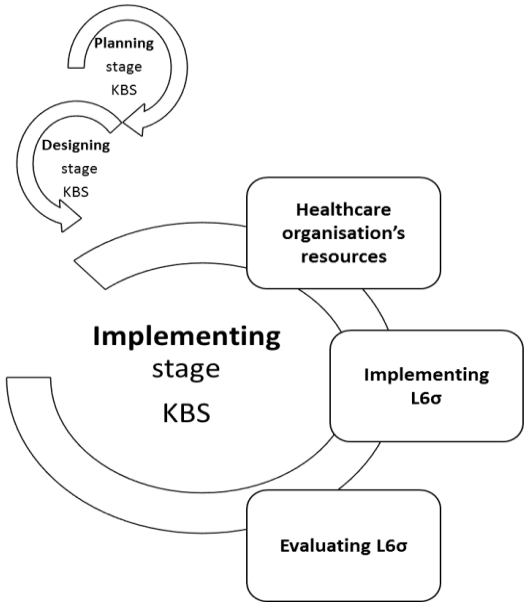


*Figure 3.4 L6σ-QMHE Framework (Implementation Stage)*

Albliwi et al. (2014) emphasised the importance of organisational resources as an element of L6σ implementation success. The feedback acquired from the discussion with research supervisors, healthcare quality management experts, published journal articles and conference papers, and received feedback has created inputs to refine the framework, according to related development steps. The selection of KPIs has been conducted based on a literature review of KPIs around the world. This selection has been filtered based on clarity of measurements, rationale for measuring this, availability of data, interpretation, and its limitation (NHS-digital, 2015).

### 3.3 The Proposed KB L6σ-QMHE Model

Based on the driven KB L6σ-QMHE framework (Al Khamisi et al., 2017a), and in order to formulate the L6σ-QMHE in a rule-based system, the researcher has contributed to the modules (Healthcare Organisation's Environment, Healthcare Governance, Healthcare Leadership, Healthcare Organisation's Resources and L6σ implementation for QMHE) and related sub-modules by developing the detailed structure with the flow of information at each stage to form the suitable model as shown in Figure 3.5. The detailed model development has taken approximately six months.

Then, the model has been presented in a conference for the purpose of refinement and further development (Al Khamisi et al., 2017b). Submitting the conceptual framework and the proposed model to referred conferences was to get a feedback from the peer-review and from the participants too. For example, Healthcare organisation's resources module was designed initially to be under strategic level but the feedback suggested moving it to be under operational level as it shows in Figure 3.5.

Basically, each module consists of KPIs where they will be used later to generate the KB rules for different variables of L6σ in healthcare based on different levels of decision-making at each organisational hierarchy. Thereafter, all the KB rules will be saved in the KB database and simplified by mixing with the GAP analysis method to accomplish the best analysis and calculation outcomes of the decision-making course. The project model is established to evaluate the healthcare institutional abilities from different angles, starting from a wide strategic level and tightening down to the most operational level.

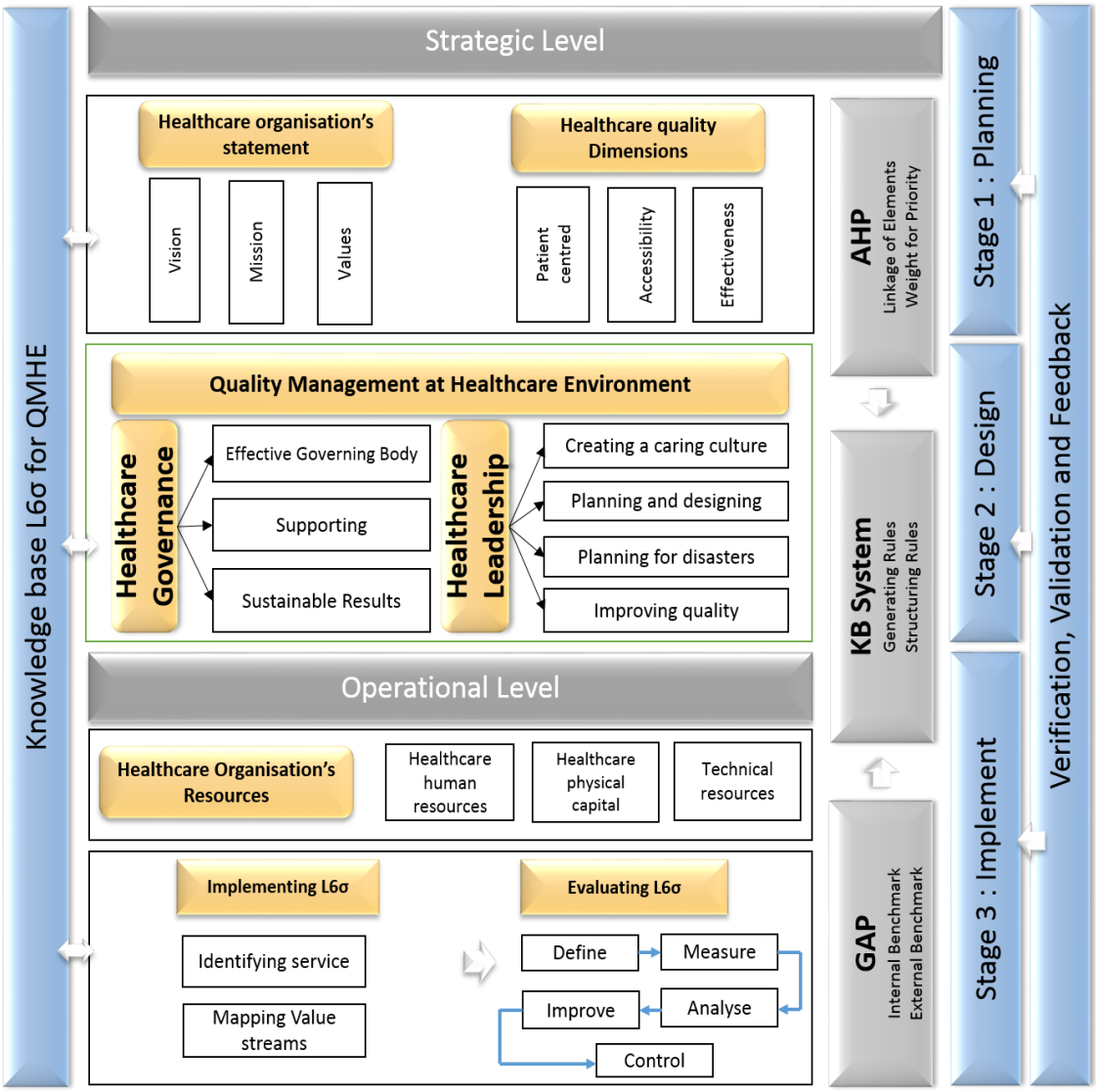


*Figure 3.5 Model of KB L6σ-QMHE*

### *3.3.1 Stage 1: Plan*

To accomplish L6σ-QMHE model as shown in Figure 3.5 reveals, the first step part of strategic level relates to formulating the plan stage. This stage consists of healthcare organisation's statement and healthcare quality dimensions. Healthcare quality dimensions have been discussed and illustrated in World Health Organisation (WHO), Accreditation Canada International (ACI), Joint Commission International (JCI), and the NHS as part of several healthcare dimensions. ACI (2016) introduced eight quality dimensions for healthcare, and these are as follows: *population focus, accessibility,*

*safety, work life, client-centered services, continuity of services, effectiveness and efficiency.* In fact, effectiveness in this research is providing the intended results whereas efficient is functioning in the way with minimum waste and efforts. Comparing with ACI, the WHO report (2006) added *equitability* and excluded *population focus and work life.* The selection of L6σ-QMHE model dimensions (*patient-centered, accessibility and effectiveness*) has been done by the researcher after a process of comparison between literatures and discussion with healthcare QM experts.

The clarity of goals, objectives and readiness of assessment are very essential at the development plan stage to look for the different aspects that affect the main target. Poister and Streib (2005) found that the most frequently reported elements were the development of goals and objectives and the development of a vision for a future followed by review of the organisational mission.

George (2003) summarised approaches to conducting a readiness assessment as: select the L6σ champion, establish a baseline of the organisation, interview top management, engage key influencers, and assess the impact of what is found. As mentioned above, the researcher is going to consider two main factors in the plan stage: the healthcare organisation's statement and assessment of healthcare quality dimensions.

### *3.3.2 Stage 2: Design*

Moving to the design stage, the first factor that needs to be considered is healthcare QM standards. JCI has divided its standards into two sections: patient-centred standards and healthcare organisation management standards. The first section focuses on clinical quality and the second section focuses on the administrative part that includes QM, leadership and governance which are considered to be the core of this research.

ACI listed 70 standards in different areas and this includes clinical and non-clinical areas, specifically, this centres on: governance, leadership, primary care, ambulatory services, critical care, diagnostic imaging, disaster preparedness, emergency, medicine, obstetric, operating rooms, surgical care, reprocessing and sterilization, and laboratories standards.

Therefore, after a systematic review of different healthcare standards such as: JCI (2010), ACI (2016, 2016a), and the NHS (2011), the author will focus on healthcare organisation management standards only. These standards include the governance and leadership standards to cover all possible QM perspective issues. As such, the research will mainly use the ACI standards to apply both perspectives (See Appendix A that declares the permission of using these standards).

Governance standards address the growing international request for an enhanced governance function to increase accountability over decision-making in healthcare organisations. According to Qmentum International (2016a), the governance standard should function as an effective governing body, supporting the organisation to achieve its mandate, be accountable, in order to achieve sustainable results. There is an entity (for example, a Ministry of Health), or a group of identified individuals (for example, a Board or Governing Body) responsible for overseeing the organisation's operation and accountable for providing quality healthcare services to its community or to the population that seeks care. This entity's responsibilities and accountabilities are described in a document that identifies how they are to be carried out (JCI, 2010).

Moving to leadership standards that addresses the growing international request for clarity regarding the roles and responsibilities of healthcare organisations and their leaders to deliver the support and infrastructure needed to drive excellence and quality

improvement in health service delivery. According to Qmentum International (2016a), the leadership responsibility states that organisations must have in place as part of their pursuit of quality and safety. The healthcare leadership must be able to create and sustain a caring culture, plan and design services, plan for disasters and emergencies and monitor, and improve quality and safety.

Governance and leadership standards must be integrated with L6σ performance measures. Accordingly, the conceptual design will consider the most suitable L6σ elements with respect to governance standards and leadership standards in order to generate L6σ for QMHE. Thus, this new product of integration has to be maintained by a decision making process to conclude the application of the conceptual design. This requires having a controlling methodology that can activate two deliverables in KB L6σ, governance standards and leadership standards, and the benchmarks between the current practise and the desired ones. The wide and positive use of GAP analysis for benchmarking and AHP for prioritisation has directed this research to integrate both methods into the KB L6σ of QMHE model.

### *3.3.3 Stage 3: Implementation*

The third stage is the implementation stage, which arises under the operational levels. At this stage, both allocating resources and implementation of L6σ are used to accomplish the selected projects after passing the initial assessments. At this stage also, the KBS will assess how the financial resources are allocated to cover human resources, capital and technical expenditures. WHO considers human resources as one of three principle health system inputs, with the other two main inputs, the existence of physical capital, and consumables (WHO, 2000).

After that, it will measure the L6σ Pre-implementing stage in the healthcare organisation with three items: its ability to select and identify the services needed based on the patient and employees requirements and needs, and its ability to draw value streams for the desired services. George (2003) summarised the phases of deployment as occurring into 4 phases; readiness assessment, engagement, mobilisation and performance.

At the Evaluating phase, a process called DMAIC will be used as a tool to improve L6σ process in the healthcare organisation. This process can be explained as: *Define* which process or product that needs improvement, *Measure* data that help set priorities and criteria, *Analyse* carefully the recorded measurements, *Improve* result of analysis accordingly, and *Control* if the implementation was successful and make sure that improvement is continuous over time (Lin et al., 2013).

It can be seen from the model diagram in Figure 3.5 that all of the stages are integrated with verification, validation, and feedback process. The feedback acquired from the discussion with research supervisors, healthcare quality management experts, published journal and conference papers (and receiving feedback) (Al Khamisi, 2017b), and using the knowledge of L6σ Black Belt (BB) and MBB holders, will used as input to refine the model accordingly, as well as use the related development steps, as part of the verification and validation process.

In this research, verification is concerning about the model's design and objectives, whereas validation is checking whether the KB system meets the customer expectations and requirements or not. This will speed up the system development process and improve the capability of implementing the KB L6σ for QM in real hospitals.

### 3.4 Structure of L6σ-QMHE Modules (Levels)

After the creation of the KB L6σ-QMHE model, the next step is to convert it into a structured model where all the modules (Levels) are recognised. This type of hierarchical level will enable the development of the required KBS, starting with the most strategic level, and ending with the most operational level as Figure 3.6 illustrates.

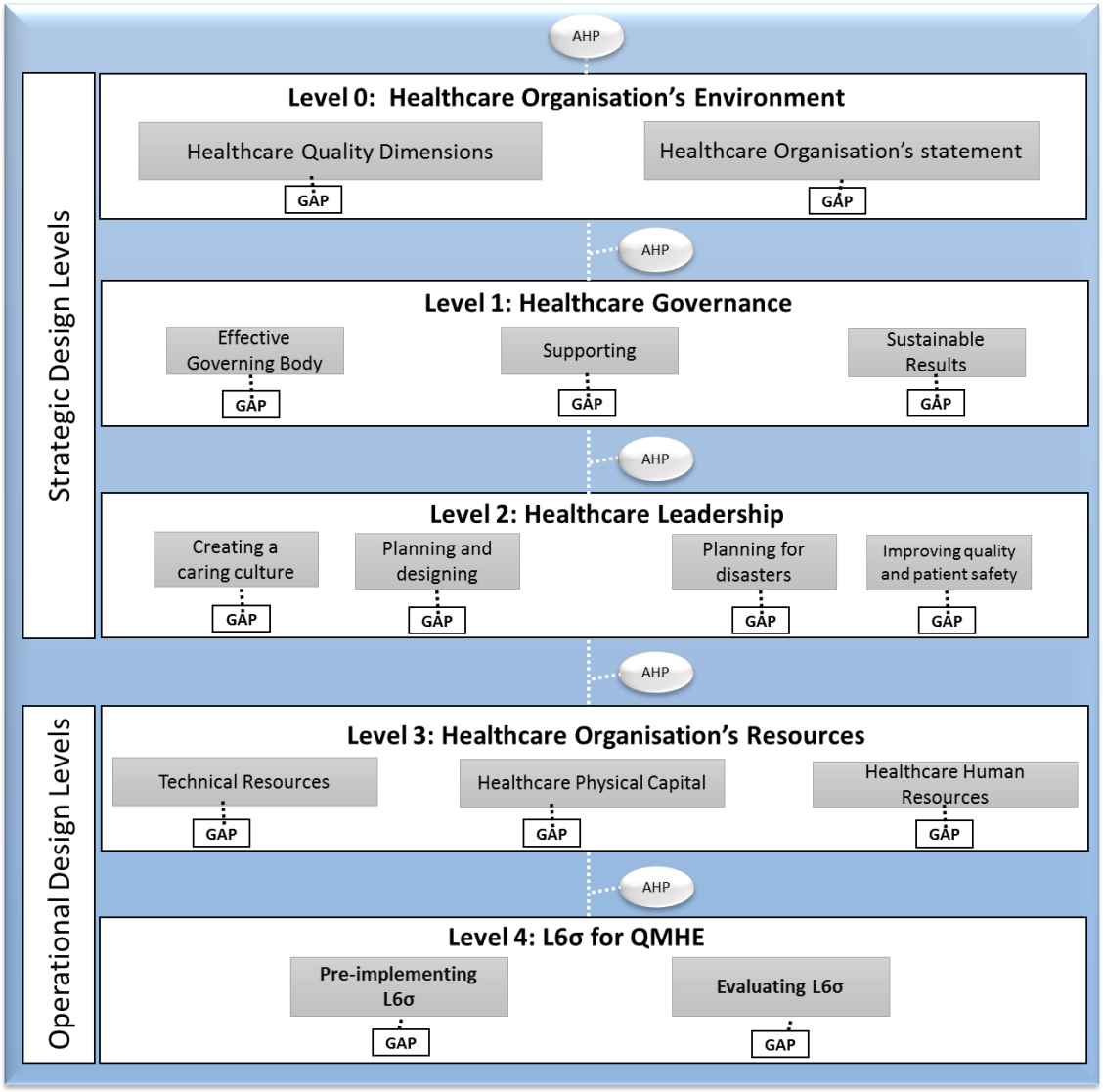


*Figure 3.6 Structure of L6σ-QMHE Modules*

#### *3.4.1 Level 0: Healthcare Organisation's Environment Module*

The organisation environment covers the basic strategic statements of the organisation. The organisation statement symbolises the entrance of the organisation's

primary identification. It states vision, mission, and values that define the main guidelines of the healthcare organisation operation. In addition, healthcare quality dimensions have been discussed and illustrated with WHO, ACI, JCI, and the NHS standards as part of several healthcare dimensions. The WHO report (2006) included 6 dimensions; effectiveness, accessibility, efficiency, patient centred, safety and equitability.

The ACI (2016a) introduced eight quality dimensions in healthcare; population focus, accessibility, safety, work life, client-centered services, continuity of services, effectiveness and efficiency. Based on literature review and discussion with experts and researcher's supervisors, the researcher will focus on three dimensions to assess quality level of healthcare organisations, which are patient-centered, accessibility and effectiveness.

For the KBS, Figure 3.7 elucidates the road map of the *Healthcare Organisation's Environment Module* with the requisite KPIs. Using this road map, the literature review, meeting experts and reading case studies, KB rules were developed using knowledge acquisition methodologies mentioned before in Section 2.9.2. These KB rules were then logically structured and programmed into ES shell.

At the beginning the user will be queried some questions that will decide whether the organisation has a well-defined statement that includes; vision, mission, objectives and values. After that, the user will be asked some questions that will decide whether the organisation has implemented and maintained the quality dimensions in its practice or not. These dimensions are: accessibility, client-centered and effectiveness.

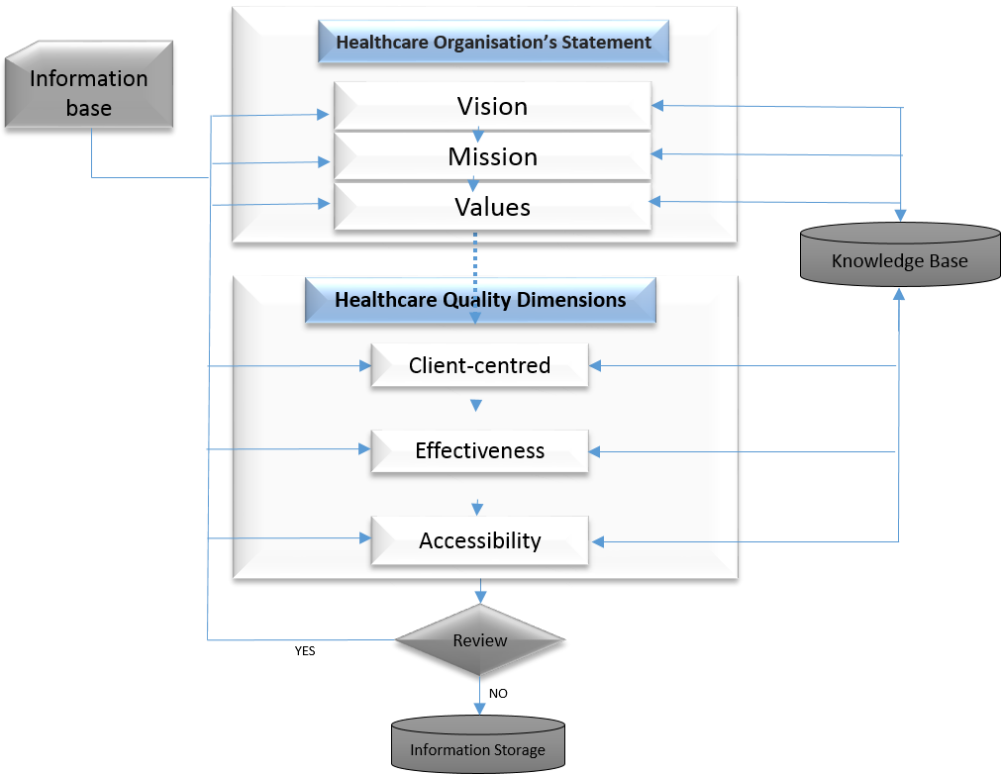


*Figure 3.7 Flowchart for Healthcare Organisation's Environment Module*

Actually, each KPI in this module is also connected to the information base as the data acquisition platform and benchmarked with the existing knowledge of best practices. For example, the KPI Vision is connected with Mission and then to values. Finally, the user (Quality managers at each targeted hospital) feedback must be reviewed and verified at the end of the process. The following example shows the KB rules of *healthcare quality dimensions sub-module*, where BP is Bad Point, GP is Good Point and PC is Problem Category, as Figure 3.1 shows.

**IF** *the healthcare organisation is delivering healthcare that is adherent to an evidence base results* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the healthcare organisation is delivering healthcare which takes into consideration the preferences of individual service users* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the healthcare organisation is measuring its services to achieve desired outcomes* (**Yes**: GP; **No**: BP-**PC-2**)

**AND** *the healthcare organisation is measuring the way individuals are treated during health system interactions* (**Yes**: GP; **No**: BP-**PC-2**)

**AND** *the healthcare organisation is measuring the productivity of its healthcare system* (**Yes**: GP; **No**: BP-**PC-2**)

**AND** *the healthcare organisation is delivering healthcare that is timely* (**Yes**: GP; **No**: BP-**PC-2**)

**AND** *the healthcare organisation is delivering healthcare that is geographically realistic* (**Yes**: GP; **No**: BP-**PC-3**)

**AND** *the healthcare organisation is delivered in a setting where skills is suitable to medical need* (**Yes**: GP; **No**: BP-**PC-2**)

*Table 3.1 Problem categories and description of GAP analysis Tool, modified from (Nawawi et al., 2008)*

| Category | Description |
|---|---|
| PC1 | This indicates a very serious problem, which should and can or can not be resolved in the short term and the result of the problem is quite likely to provide a real short-term benefits. |
| PC2 | This indicates a major problem, which is likely to have pre-requisites to the system and is better dealt with as part of an appropriate and logical improvement and implementation plan. |
| PC3 | This indicates a problem and can be dealt with now. If resolved, it is likely to produce short-term benefits. |
| PC4 | This is not a serious problem. Although it could be dealt with now, it is unlikely to produce short-term benefits. Therefore, it should only be dealt with if it is a prerequisite for other things. |
| PC5 | This is not really a good or bad point itself. The questions associated with this category are primarily asked to identify certain situations in the environment, which upon subsequent probing by succeeding questions may well reveal problems. |

The process flowchart shown in Figure 3.7 illuminates the *Healthcare Organisation's Environment Module*. Each KPI is connected with an information base as a data acquisition platform and benchmarked with the existing knowledge of best practises. User feedback must be reviewed and verified at the end of the process.

### *3.4.2 Level 1: Healthcare Governance Module*

Latest researches have advanced understanding of corporate governance of healthcare quality, highlighting the need for future empirical work to develop beyond a focus on board composition to a more detailed exploration of the internal workings of governance that influence board engagement and activities (Brown et al., 2018). In fact, the suitable governance of hospitals mainly depends on effective cooperation between governing boards and hospital management (Büchner et al., 2014). Consequently, as discussed at the beginning of this chapter and according to the Qmentum International (2016) governance perspective can be measured by assessing its governing body effectiveness, the level of support introduced to achieve its mandate, and the sustainability of achieved results. There is an entity (for example, a Ministry of Health), an owner(s), or a group of identified individuals (for example, a board or governing body) responsible for overseeing the organisation's operation and accountable for providing quality healthcare services to its community or to the population that seeks care. This entity's responsibilities and accountabilities are described in a document that identifies how they are to be carried out (JCI, 2010).

For the KBS, Figure 3.8 elucidates the road map of the flowchart of *Governance Module* with the requisite KPIs. Using this road map, literature review, meeting experts and reading case studies, KB rules were developed using knowledge acquisition methodologies mentioned before. These KB rules were then logically structured and programmed into ES shell. At the beginning the user will be queried some questions that will decide whether the organisation has an effective governing body and whether it operates according to defined roles and responsibilities, has the appropriate membership, and has a defined process for decision-making.

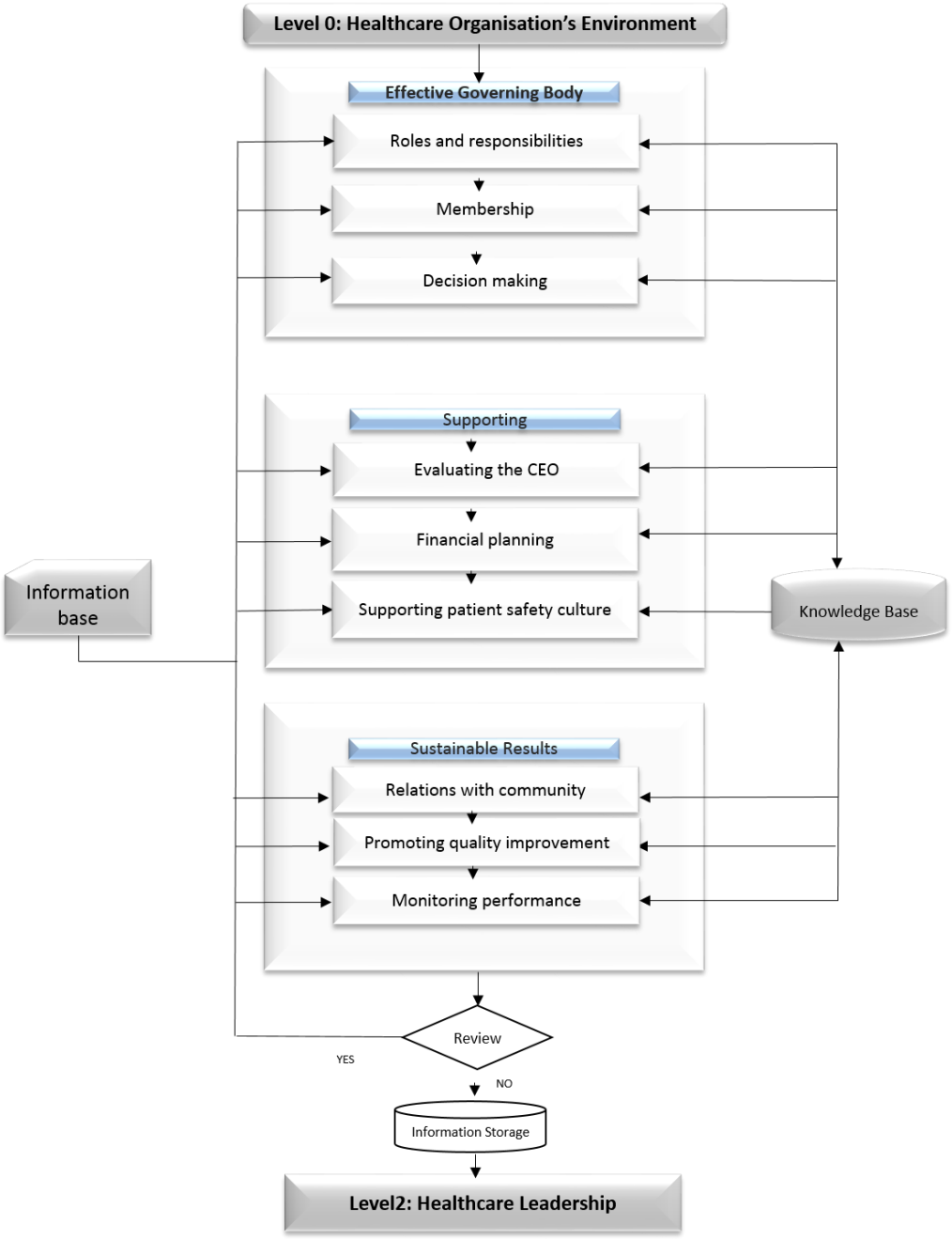


*Figure 3.8 Flowchart of Healthcare Governance Module*

After that, the system will inspect how supporting is the governing body. This should be done by assessing the process of recruiting, selecting and evaluating the chief executive, having an effective system of financial planning and controlling, supporting a culture of client safety throughout the organisation. Consequently, the user will be asked questions regarding the sustainable results. In this part the user will be asked about the strength of relationships with stakeholders and community, working with the chief

executive to promote quality improvement and monitoring, and evaluating the organisation's performance.

The following example shows the KB rules of *effective governing body sub-module*, where BP is Bad Point, GP is Good Point and PC is Problem Category, as it will be discussed later in sections 3.5.3 and 3.5.4,

**IF** *the governing body operates according to defined responsibilities* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the governing body has the appropriate membership to fulfill its roles* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the governing body has a defined process for decision-making* (**Yes**: GP; **No**: BP-**PC-2**)

**IF** *the organisation's governance structure is identified in an organisational chart.* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the governing body has written documentation that identifies its responsibilities.* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the governing body has processes in place to oversee the function of human resources management* (**Yes**: GP; **No**: BP-**PC-2**)

The process flowchart shown in Figure 3.8 illuminates the *Healthcare Governance Module*. Some KPIs may interfere with the other KPIs in other modules; this issue will be solved by generating some action rules in which the system must check and transfer data between modules in a cross-functional manner. Each KPI is connected with an information base as a data acquisition platform and benchmarked with the existing knowledge of best practises. User feedback must be reviewed and verified at the end of the process.

### *3.4.3 Level 2: Healthcare Leadership Module*

The organisation's leadership has a very vital role in confirming the base and the path towards accomplishing a high level of organisational performance. Despite that, the understanding of the abilities of effective healthcare leadership remains limited (Hargett et al., 2017). According to Higgins (2010), the change management challenge is all about the quality of leadership in health organisations.

Thus, understanding leadership and change management will be progressively significant to astounded opposition to change and to increase relationships, the core of leadership in an environment that will become more challenging (Menaker, 2009). Healthcare leaders know that managers are under increasing pressure to work smarter and more efficiently with fewer available resources (Wallick, 2002). As discussed at the beginning of this chapter and according to Qmentum International (2016a) the leadership standards can be assessed by its ability to create a caring culture, planning and designing services, planning for disasters and emergencies, and improving quality and safety.

For the KBS, Figure 3.9 elucidates the road map of the flowchart of *Healthcare Leadership Module* with the requisite KPIs. Using this road map, the literature review, meeting experts and reading case studies, KB rules were developed using knowledge acquisition methodologies mentioned before. These KB rules were then logically structured and programmed into ES shell. At the beginning, the user will be queried some questions that will decide whether the organisation has create a caring culture based on its values and whether it promotes healthy and safety environment and quality improvement.

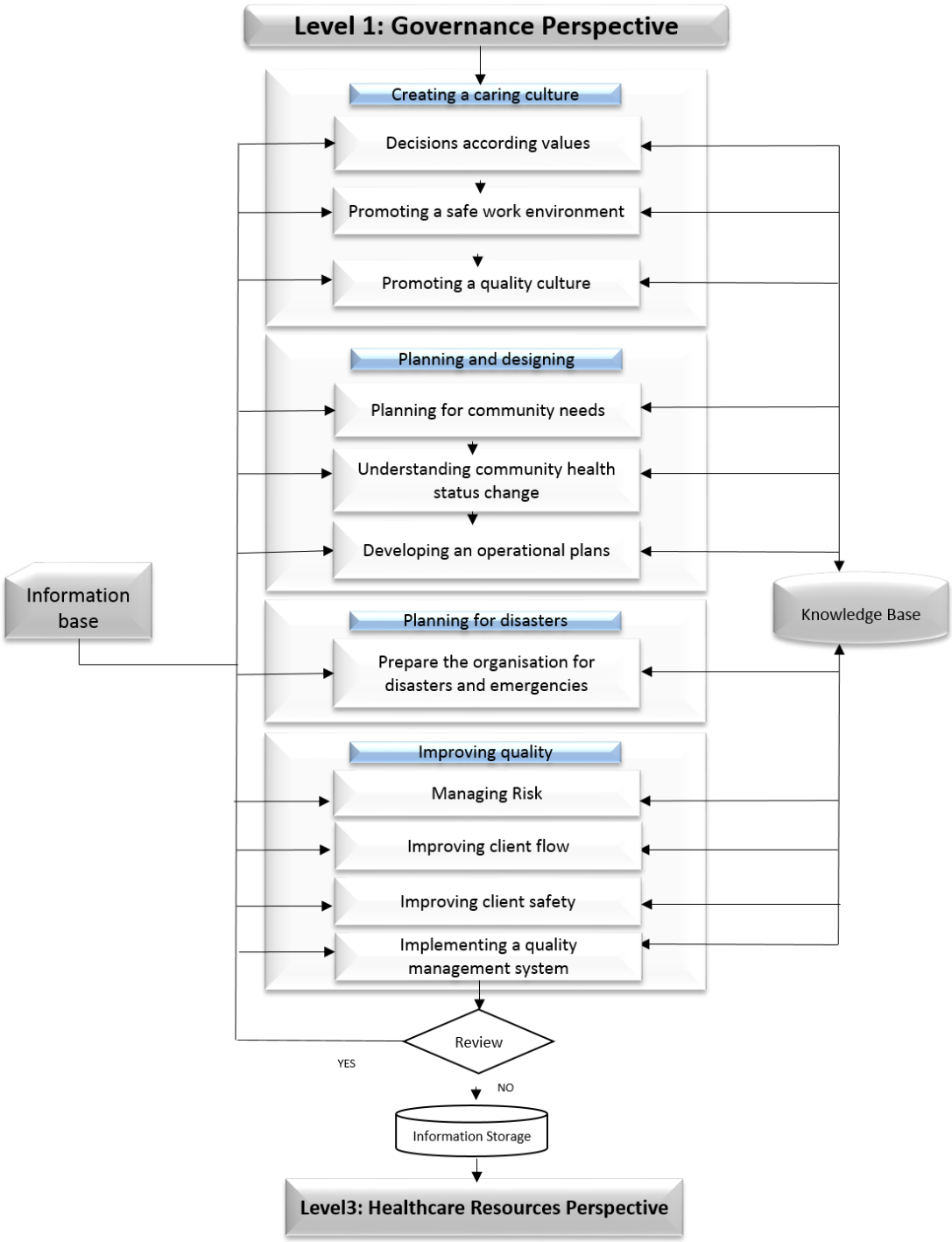


*Figure 3.9 Flowchart of Healthcare Leadership Module*

Then, the system will examine the planning and designing process to make sure if it is satisfying the community needs and response to its changes, as well as implementing an operational plan to do that. Consequently, the user will be asked questions regarding the preparedness of the organisation for emergencies and disasters.

The improvement of quality is the next part to be examined under this module. In this part, the user will be asked about the risk managing process in the organisation, client flow process, improving patient safety and developing a QM system.

The following example shows the KB rules of *creating a caring culture sub-module*, where BP is Bad Point, GP is Good Point and PC is Problem Category, as it will be discussed later in sections 3.5.3 and 3.5.4,

**IF** *the organisation's leaders deliver services according to the organisation's values* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the organisation's leaders promote a safe work environment that support a positive quality of work life* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the organisation's leaders promote a quality improvement culture throughout the organisation* (**Yes**: GP; **No**: BP-**PC-2**)

**IF** *the organisation's leaders identify a safe work environment as a strategic priority* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the organisation's leaders provide support for quality of work life* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the organisation's leaders are involved in quality of work life* (**Yes**: GP; **No**: BP-**PC-2**)

The process flowchart shown in Figure 3.9 illuminates the *Healthcare Leadership Module*. Each KPI is connected with an information base as a data acquisition platform and benchmarked with the existing knowledge of best practises. User feedback must be reviewed and verified at the end of the process.

### *3.4.4 Level 3: Healthcare Organisation's Resources Module*

Delivering healthcare proficiently needs financial resources to be accurately balanced among the many inputs used to provide health services. Huge numbers of physicians, nurses and other staff are unserviceable without sufficiently built, equipped

and supplied facilities. Available resources should be allocated both to funds in new skills, facilities and equipment, and to maintain the current structure. The WHO considers human resources as one of three principal health system inputs, with the other two main inputs i.e. the existence of physical capital and consumables (WHO, 2000).

In addition, the significance of technology and information technology systems to cover new challenges in the healthcare system is becoming progressively obvious. Technological growth powers the economic period of a portion of capital: old investments rapidly become invalid as new and upgraded technologies arise. The NHS (2008) listed more than seventeen examples of technological needs in the healthcare sector and these include: access to health information, making and managing appointments, self-diagnosis, safety and security monitoring and relationship with carers/clinicians (Alasdair Liddell, 2008). Without diagnostic equipment and medicines, the delivery of services will still be poor regardless the high knowledge and skills. In respect with physical capital, hospitals need laboratories, pharmacies, extending of new wards, adding new clinics and other small clinical facilities. This research will therefore assess the total healthcare resources based on three inputs: human resources, physical capital, and technical resources.

Using Figure 3.10 flowchart, literature review, meeting experts and reading case studies, KB rules were developed using knowledge acquisition methodologies mentioned in the previous modules. These KB rules were then logically structured and programmed into ES shell. At the beginning the user will be queried some questions that will decide whether the organisation has enough human resources, resources for their training, and the ability to cover labor cost. Then, the system will examine the physical capital of the organisation to make sure if it has enough resources for investment in buildings,

equipment, and promoting maintenance. After that, the system will inspect technical resources that are used on daily basis, and these include the usage of equipment, and information system.

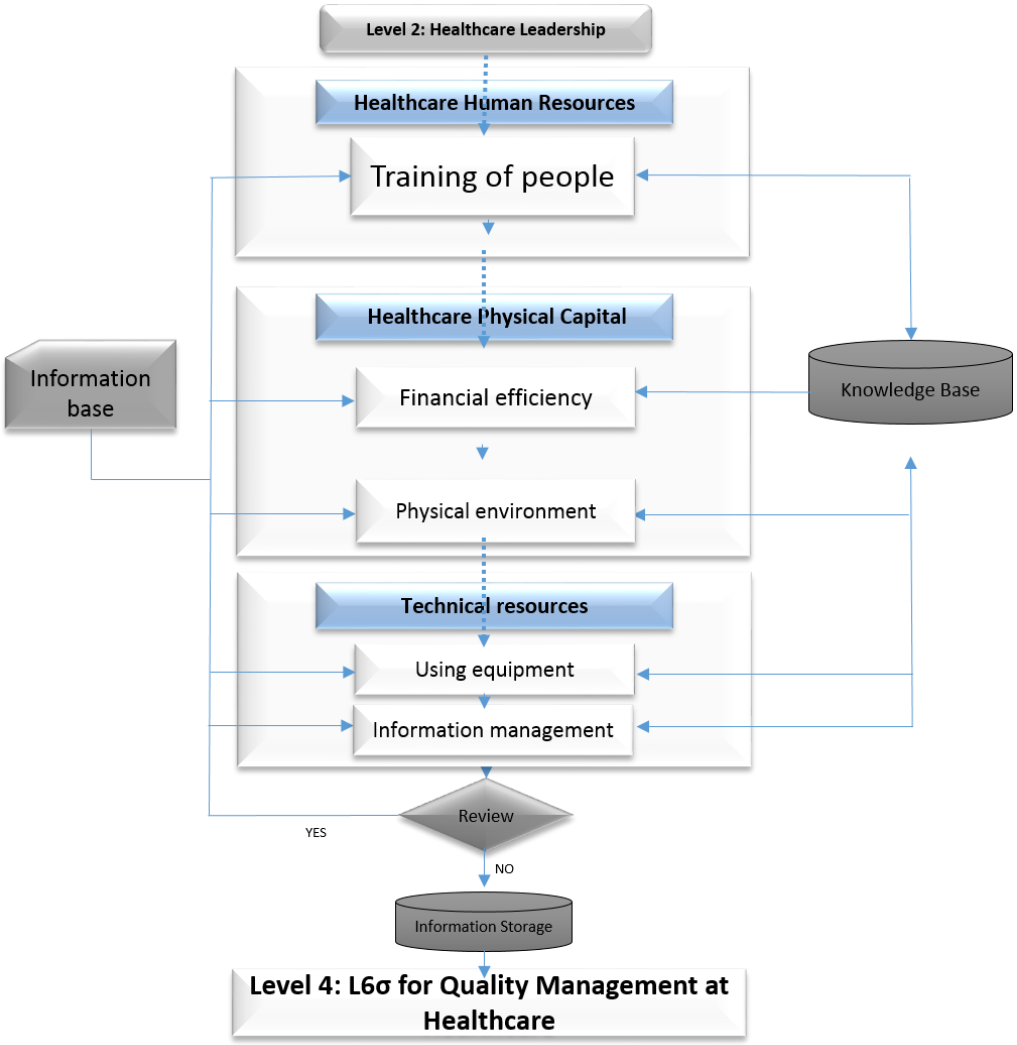


*Figure 3.10 Flowchart of Healthcare Organisation's Resources Module*

The following example shows the KB rules of *human resources sub-module*, where BP is Bad Point, GP is Good Point and PC is Problem Category, as it will be discussed later in sections 3.5.3 and 3.5.4,

**IF** *the healthcare organisation has enough number of healthcare providers* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the healthcare organisation has enough financial resource to maintain a required training for its employees according to plan* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the healthcare organisation is monitoring the increase of services introduced compared to the current human resources* (**Yes**: GP; **No**: BP-**PC-1**)

**AND** *the healthcare organisation is measuring its human resource satisfaction periodically* (**Yes**: GP; **No**: BP-**PC-1**)

The process flowchart shown in Figure 3.10 illuminates the *Healthcare Organisation's Recourses Module*. It is observable that some KPIs interfere with the other KPIs in other modules; this issue will be solved by generating some action rules in which the system must check and transfer data between modules in a cross-functional manner.

### *3.4.5 Level 4: Structure of L6σ for QMHE Module*

As discussed in Chapter 2, the integration of Lean and 6σ aims to target each and every opportunity for improvement in a particular organisation (Pepper and Spedding, 2010). George (2003), in *'Lean Six Sigma for Service'* divided the implementation of L6σ to three parts; pre-implementation, deploying and evaluation. In fact, the aim of L6σ is to delight the organisation's customers by delivering higher quality service in less time. To achieve this aim, it is important for this organisation to improve its process by eliminating defects and focusing on how work flows through the process.

L6σ for healthcare system is an improvement methodology that maximise owner's value by accomplishing the fastest level of improvement in patient satisfaction, cost, quality and process speed. In this research, the author will measure the L6σ Pre-implementing stage in the healthcare organisation with two items: its ability to select and identify the services needed based on the patient and employees requirements, and needs, and its ability to draw value streams.

The second sub-module of *L6σ Module* is an evaluation which could be accomplished by using a process called DMAIC. As discussed earlier in Chapter 2, this process can be explained as: *Define* which process or product that needs improvement, *Measure* data that help set priorities and criteria, *Analyse* carefully required measurements, *Improve* result of analysis accordingly, and *Control* if the implementation was successful and make sure that improvement is continuous over time (Lin et al., 2013). However, DMAIC methodology can be repeated if this is not successful.

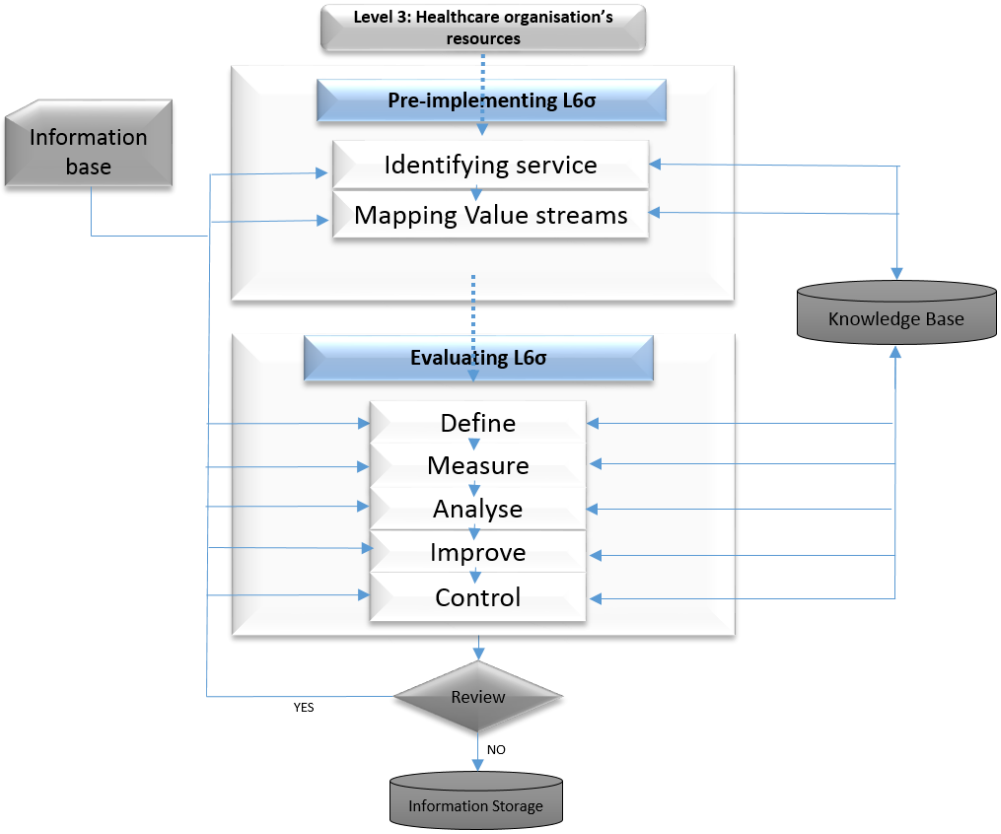


*Figure 3.11 Flowchart of L6σ for QMHE Module*

Using Figure 3.11, literature review, meeting experts and reading case studies, KB rules were developed using knowledge acquisition methodologies mentioned before.

These KB rules were then logically structured and programmed into ES shell. At the beginning the user will be queried some questions that will decide whether the

organisation has chosen a valued project with respect to clear value stream and correct prioritisation. Then, the system will examine the deployment process in combining with the L6σ for QMHE Module. Thereafter, the user will be asked questions regarding improvement as a part of L6σ.

The improvement stage will consist of DMAIC process as discussed earlier. Actually, each KPI in this module is also connected to the information base as the data acquisition platform and benchmarked with the existing knowledge of best practices. Finally, the user feedback must be reviewed and verified at the end of the process. The following example shows the KB rules of *L6σ evaluation sub-module*, where BP is Bad Point, GP is Good Point and PC is Problem Category, as it will be discussed later in sections 3.5.3 and 3.5.4,

**IF** *L6σ team agrees on what customers are affected by this project* ***(Yes: GP; No: BP-PC-2)***

**AND** *L6σ team agrees on how the present process fails to meet customers' needs* ***(Yes: GP; No: BP-PC-3)***

**IF** *as part of baselines metrics establishment, L6σ team monitors Work in Process (WIP)* ***(Yes: GP; No: BP-PC-2)***

**AND** *as part of baselines metrics establishment, L6σ team monitors defects capability* ***(Yes: GP; No: BP-PC-2)***

**IF** *L6σ team uses Scatter Plots (or any other tool) to analyse the data collected in measure stage* ***(Yes: GP; No: BP-PC-2)***

**AND** *L6σ team analyses value stream maps outcomes* ***(Yes: GP; No: BP-PC-2)***

The process flowchart shown in Figure 3.11 illuminates the L6σ for QMHE Module. It is observable that some KPIs interfere with the other KPIs in other modules; this issue will be solved by generating some action rules in which the system must check and transfer data between modules in a cross-functional manner. Each KPI is connected with an information base as a data acquisition platform and benchmarked with the existing

knowledge of best practises. User feedback must be reviewed and verified at the end of the process.

## 3.5 Methods and Techniques in Developing the Proposed KB L6σ-QMHE

In this research, the approach of a KBS with GAP and AHP will improve the design and development of KB L6σ for QMHE that will assist in decision-making in healthcare organisations, which has not been carried out in the past. Therefore, the GAP analysis will simplify the benchmarking of the existing level of the organisation compared to the preferred one, while AHP will be used to prioritise the suggested solutions based on GAP analysis and weightage criteria. Basically, the KBS/GAP/AHP hybrid system will be built using rule based software. In fact, there are different computer programs provide the facility of developing rule based systems such as; Application Manager (AM), Xpertrule and Visirule. In this research, AM will be used to build the rules and connect the items of the model.

### *3.5.1 Application Manager (AM)*

According to Nawawi (2009), Huai (2012) and Aldairi (2015), the use of the ES shell of AM Builder to develop specific KBS applications is well established, and thus the current research will follow suit to develop KB L6σ-QMHE. This ES shell, developed by Intelligent Environments Inc., allows users to design an operative separate system in a short time with a great communicating user interface. It uses the production rules technique to represent knowledge that is activated through AM objects. These objects are module, procedures, commands, windows, menus, functions, and variables (Aldairi, 2015). By using these objects, KB L6σ-QMHE will be designed in a logical presentation with the ability to store and retrieve data based on the developed KB rules.

The KB L6σ-QMHE application is normally developed with a built-in display windows tool that performs as a user interface in which the communication is driven between the system and the user. As a user-friendly interface feature, there will be a delivery to display any question, answer options, and the explanation facility in one screen.

### *3.5.2 Answering Facility and Explanation Facility*

The answer options for any question are given during the interactive mode, which will be considered based on the content and context. It might be a nearby answer, in which the options of the correct answer are given in a range of intensity or relevant practise, or an open answer in which the user must give his/her personnel experience or comments in that specific practise. However, the most appropriate answer is considered to be the best in which to deliver the correct input to the KB L6σ for QMHE model. The significance of the answering in a statement format will be measured by Problem Category (PC) in case the question is intended for GAP analysis. The scales will be in the range of PC1 to PC5 where PC1 has the higher weightage scale.

Some questions could be puzzling or difficult to understand. Therefore, the *Explanation Facility* will be used to prevent any misunderstanding by the user of the question given. It contains additional information and knowledge about key areas such as standardised definitions or statements that will help the user understand the question. Such facility will be used for the KB L6σ-QMHE model instead of using Fuzzy Logic to discover and eliminate any uncertainty in understanding the KB rules.

### *3.5.3 GAP for L6σ of Quality Management in Healthcare Environment*

The GAP analysis is a method to assess the difference between the manufacturer's (services at healthcare organisations) necessary or pre-requisites for benchmark implementation to its current status level (Mohamed, 2013). In any type of application, an audit should be conducted to assess the gap between what actually exists in a specific environment and the essential or desirable prerequisites for effective implementation (Kochhar et al., 1991).

The information needed to apply GAP could be also collected from the users through the designed questionnaire embedded in the KBS. As Table 3.1 showed, after the GAP analysis audit or questionnaire, the Problem Categories (PCs) should be recorded into two reports: all positive elements and procedures (Good Points – GPs) already existing in one report and all negative elements (Bad Points – BPs) representing non-existence of data, poor systems in other report (Khan, 1999). GAP has been integrated with the KBS as a benchmarking tool in different fields, such as supply chain management (Udin, 2004), performance measurement systems (Khan and Wibisono, 2008) and maintenance strategy and operation (Milana et al., 2014).

This research will focus on internal and external benchmarking. Internal benchmarking compares the outcomes of one department with the others in the same organisation, whereas the external benchmarking is to compare the organisation's data with different organisation in the same field. The British Quality-Foundation (2016) defines internal benchmarking as the comparison of business and operations standards within an organisation, whereas external benchmarking deals with analysing the best practises outside the organisation, which can be achieved through learning from the leading edge.

### *3.5.4 AHP for L6σ of Quality Management in Healthcare Environment*

Saaty (1980) defined AHP as a systematic analysis method established for multi-criteria decision. It considers the different phases of the process and provides an efficient result. In addition, AHP method uses measurable criteria in a hierarchical structure to break down a complex problem (Saad et al., 2016). In order to accomplish active implementation of AHP in KB L6σ-QMHE, the following procedure steps will be followed based on the method description stated in Wang et al. (2007):

a. *Determining and structuring of all elements affecting the decision-making problem:* implement L6σ for QMHE is considered to be the goal needs to be achieved in this research.
b. *Structuring the decision hierarchy:* the decision hierarchy for L6σ-QMHE is structured such that the goal is on top, followed by some criteria on the next level as shown in Figure 3.12.

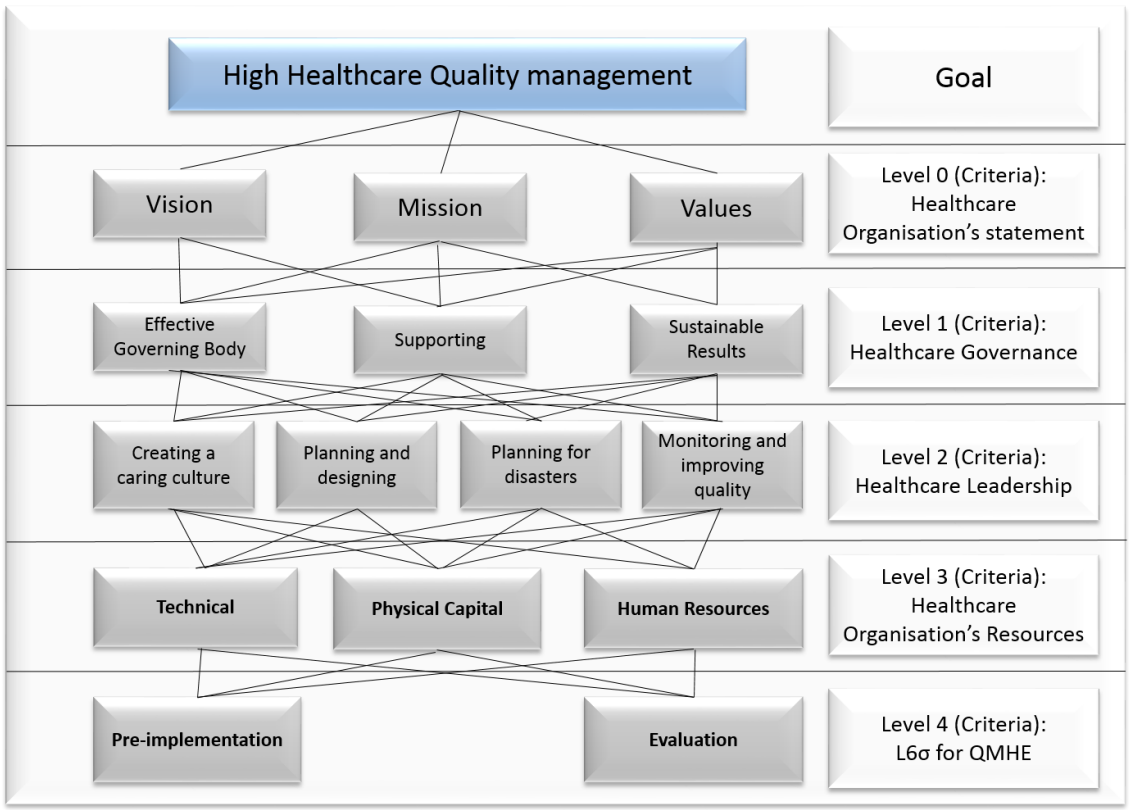


*Figure 3.12 AHP Structure for KB L6σ-QMHE*

c. *Computing of local priorities (comparison matrix)*: The hierarchy explained above starts with the goal to be achieved through AHP in KB L6σ-QMHE. The next levels show the criteria used to achieve this goal. At Level 0, healthcare organisation's statement module relates to assessing vision, mission and values. This level is linked to the sub-criteria at Level 1; governance module. This level has 3 sub-criteria: effective governing body, supporting, and sustainable results. Again, the upper level influences the next sub-criteria, which belongs to the leadership module at Level 2. Moving to Level 3, the criteria of Healthcare Organisation's Resources will be assessed. It consists of three sub-criteria; human resource, physical capital resource, and technical resource. These sub-criteria will as a result influence Level 4, L6σ for QMHE module. Table 3.2 shows the

comparison matrix used to give local priority for each factor in all levels that will be used in Chapter 5.

*Table 3.2 Example of pair-wise Matrix*

| | PC1 | PC2 | PC3 | PC4 | PC5 |
|---|---|---|---|---|---|
| PC1 | 1 | 2 | 3 | 4 | 5 |
| PC2 | 1/2 | 1 | 3/2 | 4/2 | 5/2 |
| PC3 | 1/3 | 2/3 | 1 | 4/3 | 5/3 |
| PC4 | 1/4 | 2/4 | 3/4 | 1 | 5/4 |
| PC5 | 1/5 | 2/5 | 3/5 | 4/5 | 1 |

d. *Obtaining alternatives ranking (weightage of the PC):* The priorities of the lower level will be weighted by the priorities acquired from the comparison above. As an example, PC3 is important 3 times compared to PC1 and PC5 is 5 times important than PC1. Therefore, the highest scale of the most severe problem (PC1) is 5, and the lowest scale (PC5) is 1. This is shown in Table 3.3.

*Table 3.3 Weightage Summary of Problem categories*

| **Problem Category** | PC1 | PC2 | PC3 | PC4 | PC5 |
|---|---|---|---|---|---|
| **Weight** | 5/1 =5 | 5/2 =2.5 | 5/3 =1.66 | 5/4 =1.25 | 5/5 =1 |

e. *Logical consistency:* According to pairwise comparison matrices, the upper level element is compared to the one immediately below. The answer is then classified into GPs, which are a credit to the organisation, or BPs, where the organisation must make improvements.

*Table 3.4 Illustration of the weighting in AHP, according to Saaty (1980), modified from Hopfe et al. (2013)*

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | **Equally important** | Two elements have equal important |
| 2 | **Moderately more important** | Experience or judgment slightly favours one element |
| 3 | **Strongly more important** | Experience or judgment strongly favours one element |
| 4 | **Very strongly more important** | Dominance of one element proved in practice |
| 5 | **Extremely more important** | The highest order dominance of one element over another |

As Table 3.4 shows, these BPs are categorised based on the level of importance and the severity effect of the PC in order to be matched with other BPs as can be seen in Table 3-1. They emphasise that AHP will help decide this consistency based on calculating the Consistency Ratio (CR). The CR should be less than or equal to 10%; otherwise, there will be inconsistency in the matrix, and hence the subjective judgment must be revised.

The CR can be calculated by the equation below:

$CR = \frac{CI}{RI}$ , where CI is the Consistency Index (degree of consistency) and RI is the Random Consistency index, which is normally known, as The Consistency Index is calculated by: = $\frac{\lambda max - n}{n-1}$ , where n is the size of comparison matrix and $\lambda\ max$ is the largest eigenvalue in the matrix (Saaty, 1990).

An example of the AHP process is a selection of a hospital to do surgery as shown in Figure 3.13. The overall goal is to select a hospital suitable for appendectomy surgery. The user has 4 main criteria for this selection: safety, cost, length of stay and service.

Criteria of safety has 4 sub-criteria including infection prevention, antibiotics usage, history of medication errors and cleanness. The service criterion has two sub-criteria and these include reception, and admission environment. All these sub-criteria will help the decision makers to get eight hospital alternatives. The final one will be chosen based on the weight of each alternative as discussed.

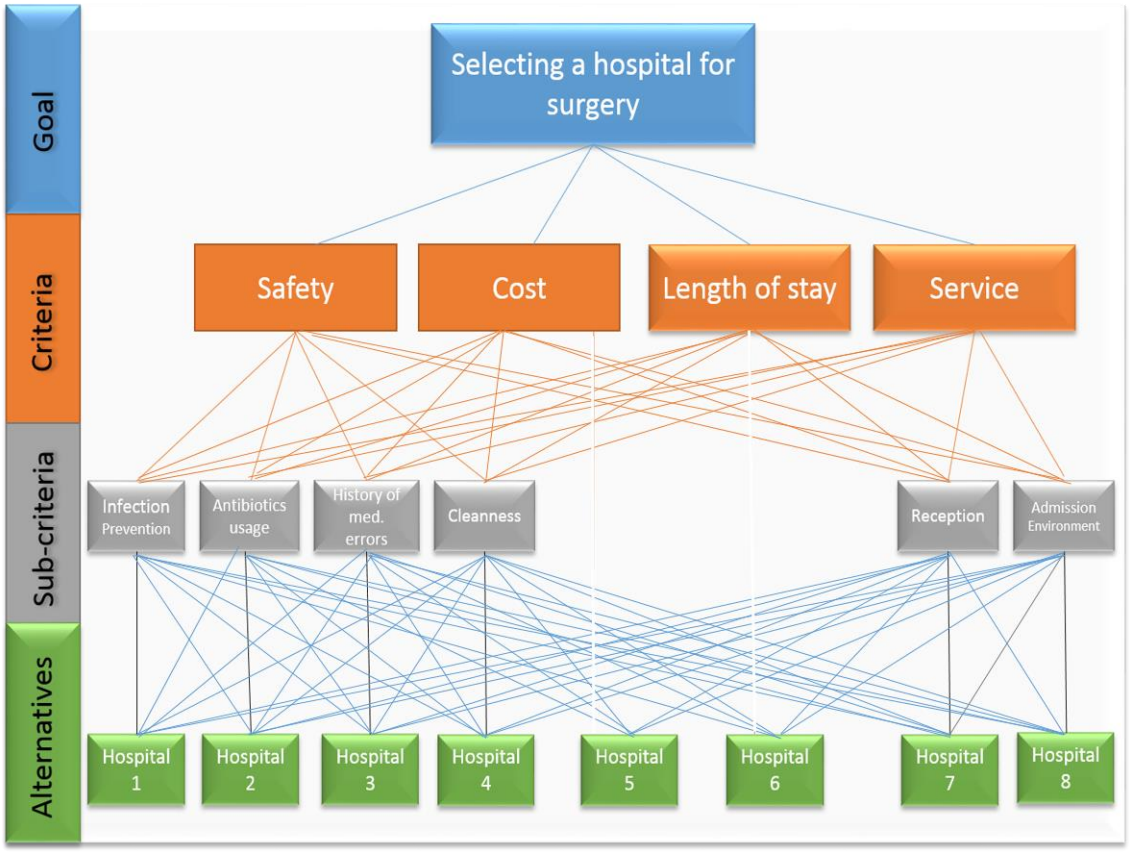


*Figure 3.13 AHP of selecting a hospital for a surgery*

For easy Priority Vector (PV) calculations, the researcher will use *Super Decision Software*. It is a decision-making software, which works based on two multi-criteria decision making methods that has been explained above. In addition, it has a facility to justify decisions, and it enables the calculations to move forward quickly.

### 3.6 Chapter Summary

In order to develop an effective KB L6σ-QMHE system, this chapter has defined the main practical steps of building the conceptual framework of this system from the literature review. This chapter explained the transformation of the conceptual framework into a hybrid KB L6σ model of QMHE that arranged in a decision level hierarchy in which the KPIs were considered. The developed framework and the transformed model have been refined and improved based on the feedback received from publishing them in as conference papers.

Initially, the transformed model showed that the *planning stage*, in which the healthcare organisation's statement was recognised and healthcare quality dimensions were assessed. Then, the phase was extended to include the *designing stage*, which included the main area of this research that deals with the core assessment components of the KB L6σ-QMHE system (governance and leadership modules).

After that, the *implementation stage* rose to represent the healthcare organisation's resources were recognised and L6σ implementation was assessed. It also discussed the two methodologies that should be integrated with the KBS; GAP and AHP. Finally, the *AM application* software that was used for building the KBS, and the *super decision* software that was used for AHP calculation were explained. The structure of all levels in the KB L6σ-QMHE model for the three stages will be shown in detail in Chapter.

# Chapter 4: Development of KB L6σ-QMHE System

## 4.1 Introduction

This chapter covers the third and the fourth objectives of the research by focusing on a full development of the KB L6σ-QMHE system. It illuminates on all levels in the structure of the KB L6σ-QMHE model for the three stages as labelled and reprinted from Chapter 3. This includes acquiring the knowledge rules and related knowledge structure for each module of the system (demonstrating the process of knowledge acquisition by the *Knowledge Engineer*). The development of flow charts and KB rules are based on a literature review, extensive review with research supervisors, industry experts, standards, publications, feedback. The researcher met eight experts in the field of QMHE and L6σ as seen in Appendix B from 26 June 2017 to 3 September 2017 and authorised by the University of Bradford as seen in Appendix D.

The interviewed experts were selected based on their experience in the field of healthcare QM and L6σ from 5 different working areas. The first interview was conducted on 10$^{th}$ of July 2017 with the General-Director of the National Quality Assurance Centre. He had more than 20 years' experience in the field of healthcare QM. Recently, he has appointed as WHO Regional Director for the Eastern Mediterranean by WHO's Executive Board. The second healthcare QM expert has been interviewed was working as a Director of Development and Quality at Sultan Qaboos University Hospital (tertiary hospital) and Oman Medical Specialty Board for more than 10 years. The next 3 experts have been interviewed are currently working at the QM directorate in Sultan Qaboos University Hospital. These experts have long experience in the field of healthcare QM extends up to 20 years.

To acquire knowledge about L6σ implementation, the researcher has interviewed 3 experts in this field. Two of these experts have an academic experience since they are currently working at the Engineering school in Sultan Qaboos University, and the last one is a MBB L6σ holder in a private company.

As part of the preparation process for the interview, the researcher has create an interview form which contains the five levels (modules) of the proposed system. Appendix C shows Level 0 form. Each module consists of KPIs that recognised and refined from systematic literature review, conferences' feedback and supervisors' discussion. During the interview, the experts were asked how to assess each KPI in the system. Their inputs, with literature reviews and international healthcare standards, were used to create KB rules.

These rules are reformatted into structured questions, with which it becomes easy for the user (participant) to interact. These questions are designed to capture both qualitative and quantitative information for the current research across all levels bearing in mind the identification of GAP analysis in each aspect. This is followed by applying the AHP technique to determine which aspect has priority over the other in order to achieve the KB L6σ-QMHE benchmark standard as seen in Figure 3.6.

The system provides the facility for the explanation of some rules that are ambiguous or difficult for the user to understand. In fact, it contains guidelines and referenced quotes which describe the importance of that specific rule in a particular environment. This will help in giving confident answers that will lead to a realistic solution.

For demonstration purposes, and due to the large number of KB rules involved, the discussion of each module will be followed by key rules only. For the complete KB

L6σ-QMHE system (Level 0–Level 4), 964 KB rules have been developed and structured. The following KB set rules illustrates a generic example of a typical rule-based structure in L6σ-QMHE:

***IF*** *the governing body works in collaboration with the organisation's leaders to develop the organisation's mission statement* ***(Yes: GP; No: BP-PC-1)***

***AND*** *the governing body works in collaboration with the organisation's leaders to implement the organisation's mission statement* ***(Yes: GP; No: BP-PC-1)***

***AND*** *when developing the mission statement, the governing body and the organisation's leaders seek input from organisation staff* ***(Yes: GP; No: BP-PC-1)***

***AND*** *when updating the mission statement, the governing body and the organisation's leaders seek input from organisation staff* ***(Yes: GP; No: BP-PC-1)***

***AND*** *when developing the mission statement, the governing body and the organisation's leaders seek input from partners* ***(Yes: GP; No: BP-PC-2)***

***AND*** *the governing body consults regularly with government to confirm the appropriateness of the organisation's core services* ***(Yes: GP; No: BP-PC-1)***

***AND*** *the governing body, with the organisation's leaders, reviews the mission statement to reflect changes in the environment* ***(Yes: GP; No: BP-PC-3)***

The above KB rules are reformatted into questions as shown in Figure 4.2. It is very important for the questions to be clearly defined in a logical order. The KB rules are fired based on user response for a particular question and related subsequent questions. Another key aspect in KB L6σ-QMHE is the accurate categorisation (*Problem Category*) of each rule which has been determined through a literature review, interviews with healthcare QM experts, L6σ MBB, and discussion with supervisors.

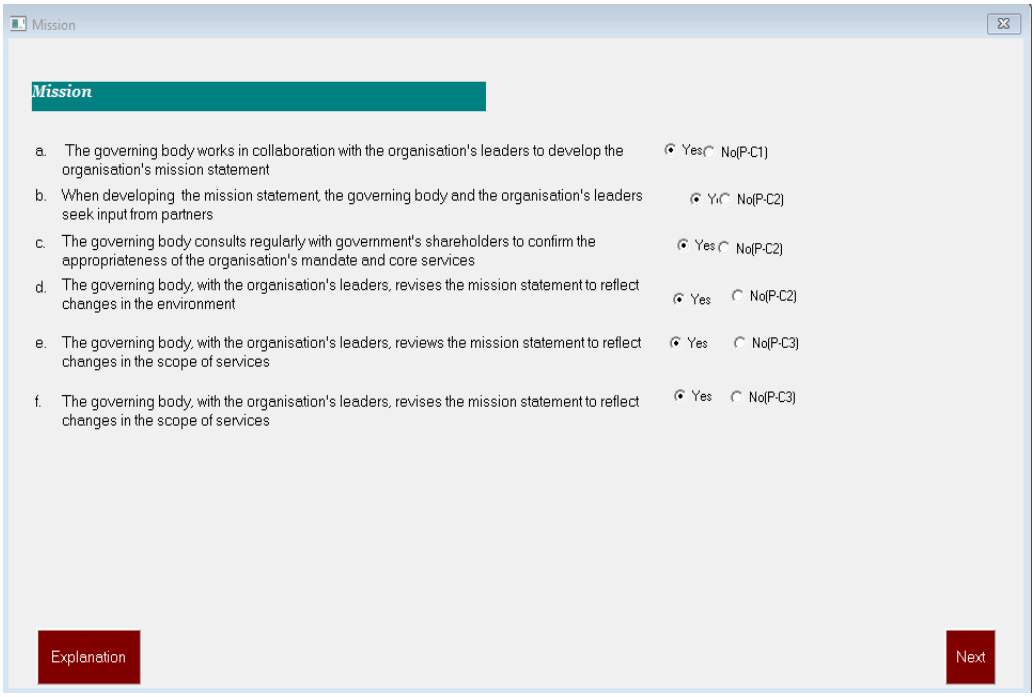


*Figure 4.1 Generic Example of KB Rules Questions*

Figure 4.1 shows a print screen for part of the reformatted rules which relate to the *healthcare statement sub-module* for the L6σ-QMHE environment. It starts by asking the user, if the governing body is working in collaboration with the organisation's leaders to develop the organisation's mission statement**.** If the answer is 'Yes', the system will count it as a good point and will move to the next question, which will ask about involving partners in the development of the organisation's mission statement. If the answer is 'No' then it signifies a serious gap in the current environment and that will be counted as a critical aspect in the KB L6σ-QMHE. Each negative answer has been prioritised in terms of importance, through a categorisation of the problem into five areas (Problem category 1 to 5). *Problem category 1* is assigned for this question because it indicates a very serious problem if this is not applicable in the healthcare organisation.

In order to overcome fuzziness and ambiguity in understanding the KB questions, the KB L6σ-QMHE model utilises the *Explanation facility* which is illustrated in Figure 4.2, as a typical example exploring questions in the *evaluation of L6σ sub-module.* The

current research has not used fuzzy logic for determining and eliminating any uncertainty in the KB rule's understanding.

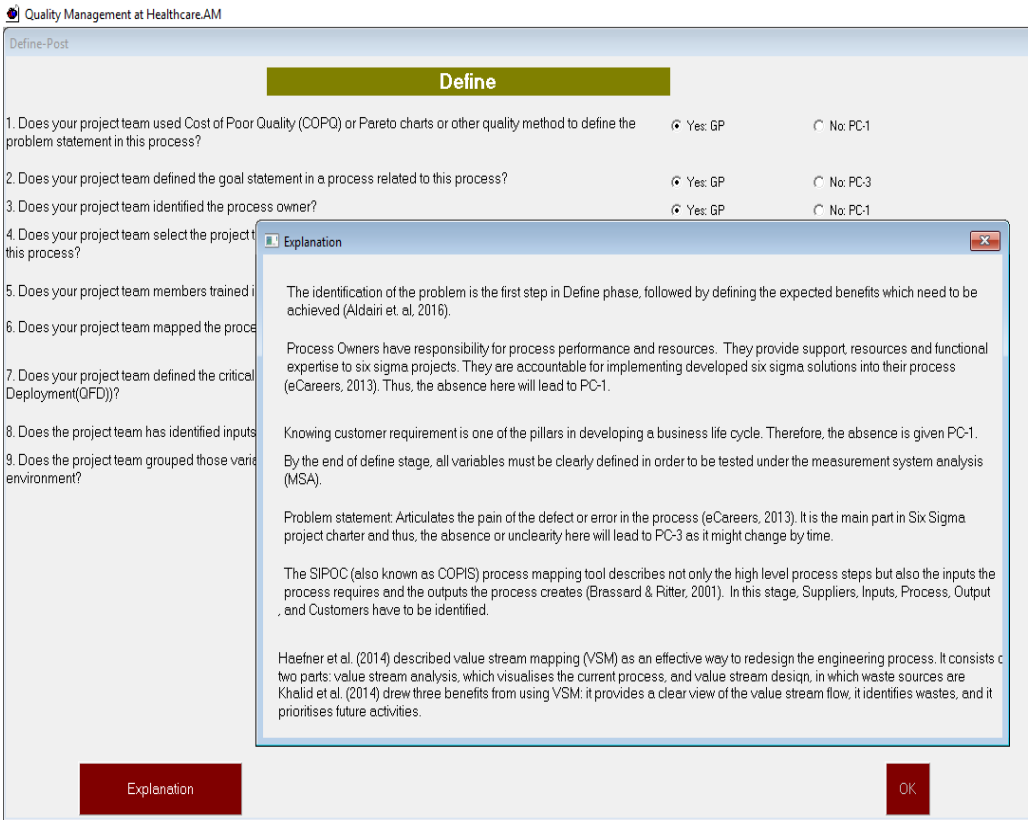


*Figure 4.2 A Typical Example of Explanation Facility in KBS*

However, after being explicit in each question, the research predicts some terms may still misguide the user, and this is because of their level of understanding which can ultimately lead to wrong answers and consequently invalid recommendations. Therefore, the *Explanation* box that includes additional knowledge information that helps the user to choose the right answer has been provided and eliminates the fuzziness.

The following sections will discuss in detail the interrelated aspects for each level within the KB L6σ-QMHE System.

### 4.2 Level 0: Healthcare Organisation's Environment

The *Healthcare Organisation's Environment* is the first module that needs to be investigated. This level helps to capture data about the healthcare organisation's statements and about the organisation's quality dimensions. The user will be in the beginning queried some questions that will decide whether the organisation has a well-defined statement that includes; vision, mission and values. After that, the user will be asked some questions that will decide whether the organisation has implemented and maintained the quality dimensions in its practice or not.

The rules developed in the module will establish relationships, converting that data into information. *Level 0* can be illustrated in the model diagram shown in Figure 4.3.

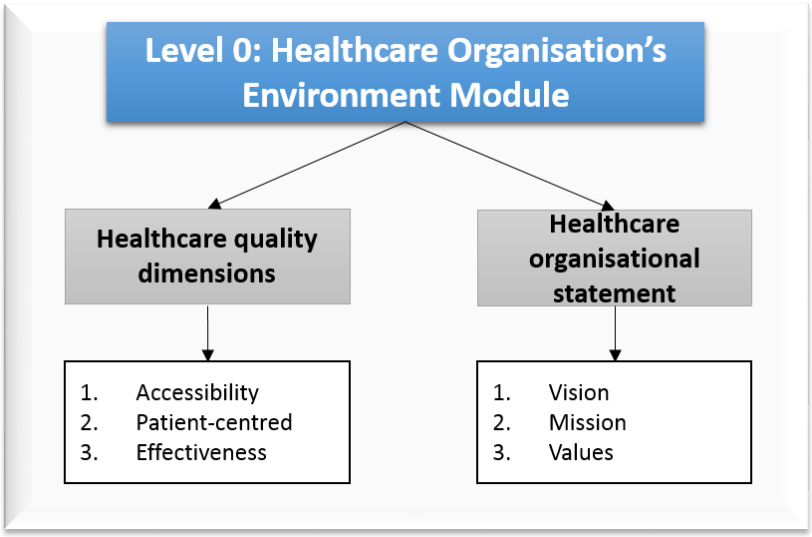


*Figure 4.3 IDEF0 Model for Healthcare Organisation's Environment*

By comparing the level of *Healthcare Organisation's Environment* with the system benchmark, the module will convert that information into recommendations about which aspects need to be improved in a prioritised manner.

### *4.2.1 Healthcare Organisational statement*

The aim of this sub-module is to measure the overall healthcare organisation's statement that represents the entrance of the organisation's primary identification. It states vision, mission, and values that define the main guidelines of the healthcare organisation's operation. Figure 4.4 illustrates that the assessment of *healthcare organisation's statement* is based on evaluating its vision, mission, and values.

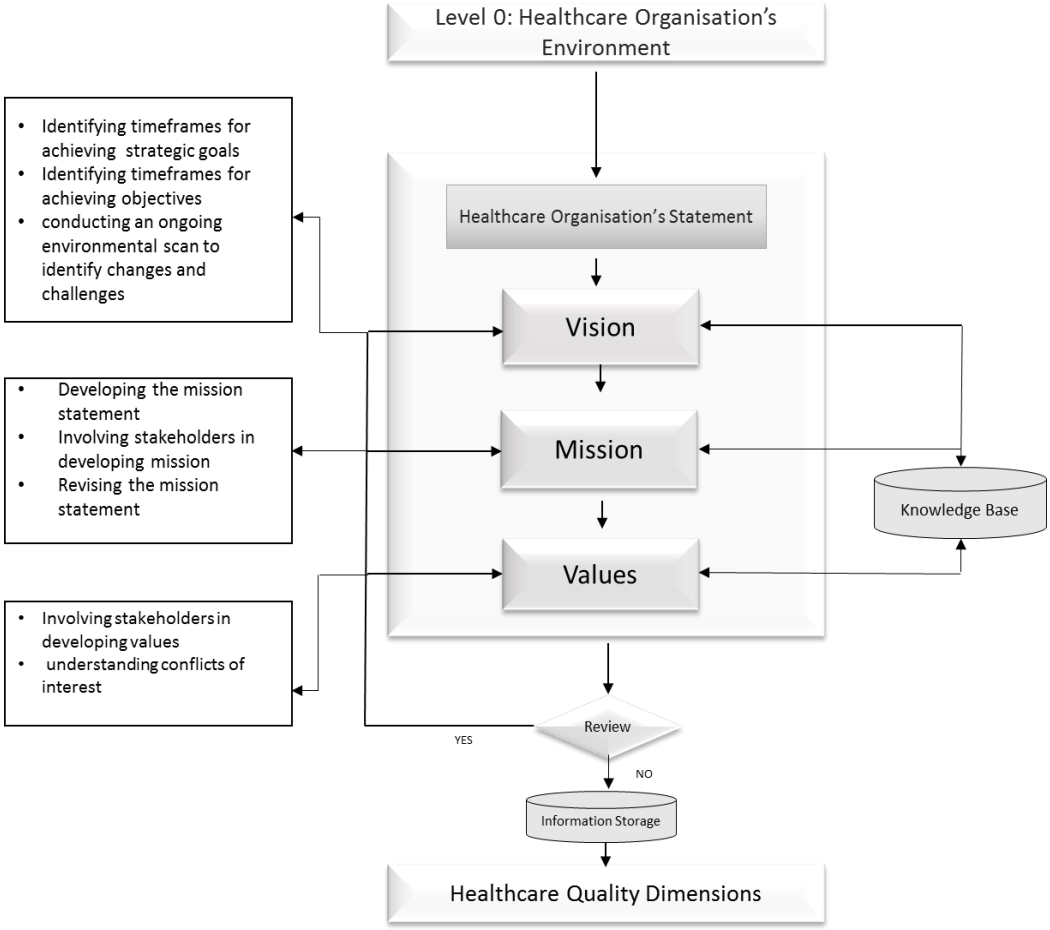


*Figure 4.4 Process flow chart of healthcare organisation's statement sub-module*

The following example of KB rules set is generated within the *healthcare organisation's statement* sub-module:

**IF** *the governing body provides guidance to the organisation's leaders as they develop the organisation's vision* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body, in consultation with the chief executive or senior director, identifies timeframes for achieving the strategic goals* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body, in consultation with the chief executive or senior director, monitors timeframes for achieving objectives* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body works with the organisation's leaders to conduct an ongoing environmental scan to identify changes* ***(Yes: GP; No: BP-PC-3)***

**AND** *the governing body ensures that the strategic plan is adjusted to reflect the information gathered in the environmental scan* ***(Yes: GP; No: BP-PC-2)***

**IF** *the governing body works in collaboration with the organisation's leaders to develop the organisation's mission statement* ***(Yes: GP; No: BP-PC-1)***

**AND** *when developing the mission statement, the governing body and the organisation's leaders seek input from organisation staff* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body consults regularly with government to confirm the appropriateness of the organisation's mandate and core services* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body, with the organisation's leaders, reviews the mission statement to reflect changes in the environment* ***(Yes: GP; No: BP-PC-3)***

**IF** *the governing body works with the organisation's leaders to define the organisation's values statement* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body has a formal process to understand conflicts of interest* ***(Yes: GP; No: BP-PC-3)***

In the above KB rules, the system starts with questioning the user, if the governing body provides guidance to the organisation's leaders as they develop the organisation's vision or not. The system has categorised the organisation as having a major problem with category PC-1, if the governing body does not provide guidance to the organisation's leaders as they develop the vision. This is also applicable to other KPIs that measure quality of the vision in the healthcare organisation, and this includes; identifying timeframes for achieving the strategic goals and conducting an ongoing environmental scan to identify changes.

In addition, the user will be asked if the governing body works in collaboration with the organisation's leaders to develop the organisation's mission statement or not.

Like vision, the system has categorised the organisation as having a major problem with category PC-1, if the governing body does not collaborate with organisation's leaders as they develop the mission. This is also applicable to other KPIs that measure mission's quality in the healthcare organisation such as; seeking input from organisation staff when developing the mission statement, confirming the appropriateness of the organisation's mandate and core services and reviewing the mission statement to reflect changes in the environment.

Furthermore, the user will be asked if the governing body works with the organisation's leaders to define the organisation's values statement or not. Like vision and mission, the system has categorised the organisation as having a major problem with category PC-1, if the governing body does not provide guidance to the organisation's leaders as they develop the values. This is also applicable to other KPIs that measure value's quality in the healthcare organisation such as; the availability of formal process to understand conflicts of interest.

In summary, each sub-module with related dimensions is linked with the information base and benchmarked with the existing knowledge of the L6σ-QMHE standard through the KB database. The user feedback must be reviewed and verified at the end of the process.

### *4.2.2 Healthcare Quality Dimensions*

The aim of this sub-module is to measure the overall *healthcare quality dimensions* in the organisation. As discussed in Chapter 3 that based on a systematic literature review and discussion with experts and researcher's supervisors, the researcher will focus on three dimensions to assess quality level of healthcare organisations which are patient-centered, accessibility and effectiveness. Figure 4.5 illustrates that the

assessment of *healthcare quality dimensions* sub-module is based on evaluating patient-centered, accessibility and effectiveness.

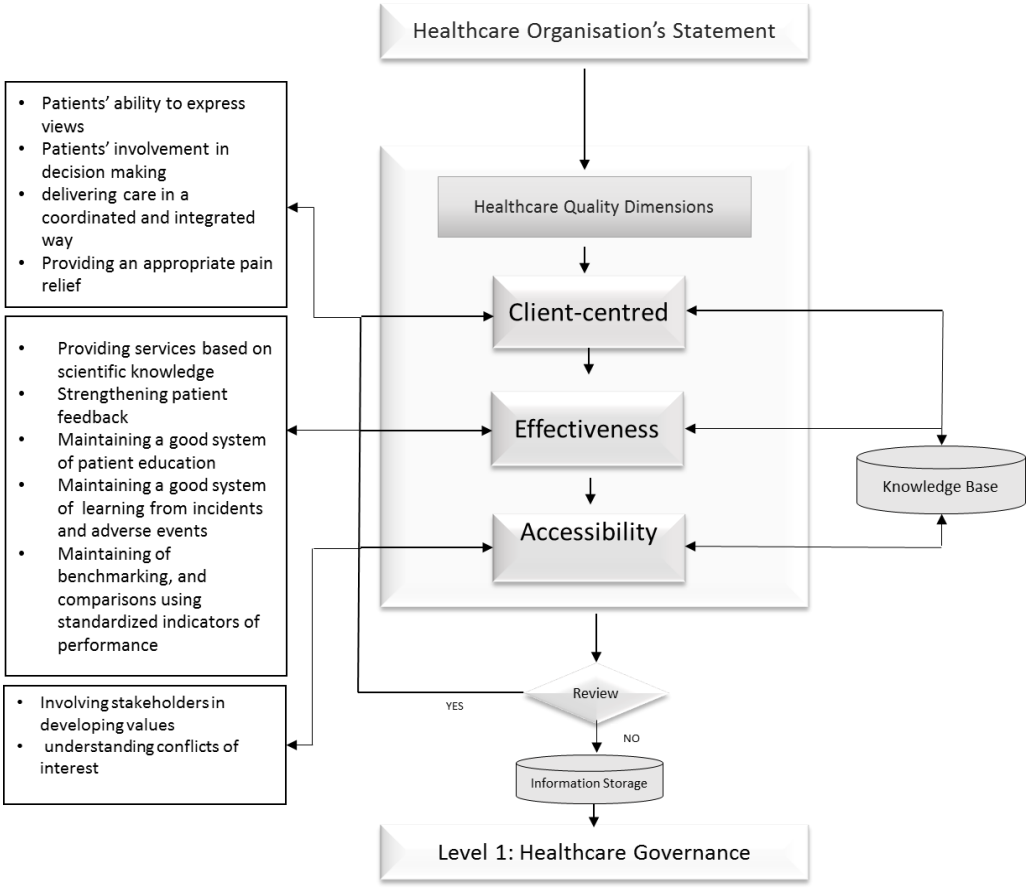


*Figure 4.5 Process flow chart of healthcare quality dimensions sub-module*

The following example of KB rules set is generated within the *healthcare quality dimensions* sub-module:

**IF** *patients feel able to express views* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *patients feel able to be involved in decision-making according to their preferences* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *patients have a representative in hospital board* ***(Yes: GP; No BP-PC-1)***

**AND** *patient-centered communication delivered by healthcare providers has been associated with better patient emotional health* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *patient-centered communication delivered by healthcare providers has been associated with better long-term patient psychosocial adjustment.* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**IF** *healthcare organisation is providing services based on scientific knowledge* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is delivering healthcare that is adherent to an evidence base* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is strengthening patient feedback (****>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is maintaining a good system of patient education* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is maintaining a good system of learning from adverse events* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is maintaining a use of performance targets* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is maintaining of public disclosure of performance (****>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**IF** *healthcare organisation is delivering healthcare that is timely* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is delivering healthcare that is geographically realistic* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is delivering healthcare in a setting where skills and resources are suitable to medical need* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is considering disabled patient access during building constructions* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

**AND** *healthcare organisation is providing enough parking for patients' cars and their families* ***(>90%: GP; 80-90%: BP-PC-4; 70-80%: BP-PC-3; 60-70%: BP-PC-2; <60%: BP-PC-1)***

In the above KB rules, the user will be asked about the extent that patients feel able to express views in the organisation. The system has offered the user a range of percentage starting from above 90% which is considered to be a GP to less than 60%

which considered to be a major problem PC-1. This is also applicable to other KPIs that measure this quality dimension in the healthcare organisation such as; involving patients in decision-making according to their preferences, associating healthcare providers with a better patient emotional health, and long-term patient psychosocial adjustment.

In addition, the user will be asked about the extent to which the healthcare organisation is providing services based on a scientific knowledge. The system has offered the user a range of percentage starting from above 90% which considered to be a GP to less than 60% which is considered to be a major problem PC-1. This is also applicable to other KPIs that measure this quality dimension in the healthcare organisation such as; strengthening patient feedback, maintaining a good system of patient education, maintaining a good system of learning from adverse events, maintaining use of performance targets and maintaining of public disclosure of performance.

Furthermore, the user will be asked about the extent that the healthcare organisation is timely in delivering healthcare to patients. The system has offered the user a range of percentage starting from above 90% which is considered to be a GP to less than 60% which is considered to be a major problem PC-1. This is also applicable to other KPIs that measure this quality dimension in the healthcare organisation such as; delivering healthcare in a geographically realistic, delivering healthcare in a setting where skills and resources are suitable to medical need, considering disabled patient access during building constructions, and providing enough car parking for patients' cars and their families.

### 4.3 Level 1: Healthcare Governance

The *Healthcare Governance* is the second module that needs to be examined. This level helps to capture data about the organisation’s governing body and how it gives

support to leaders. It also helps to measure the sustainable results to promote quality improvement, monitoring and evaluating organisation's performance. The user will be in the beginning queried some questions that will decide whether the organisation's governing body is working effectively or not.

After that, the user will be asked some questions that will decide whether the governing body is monitoring and evaluating the chief executive and supporting the culture of safety in the organisation or not. Moreover, the user will be asked some questions that will decide whether the governance is promoting the quality improvement and evaluating organisation's performance or not. The rules developed in the module will establish relationships, converting that data into information. *Level 1* can be illustrated in the model diagram shown in Figure 4.6.

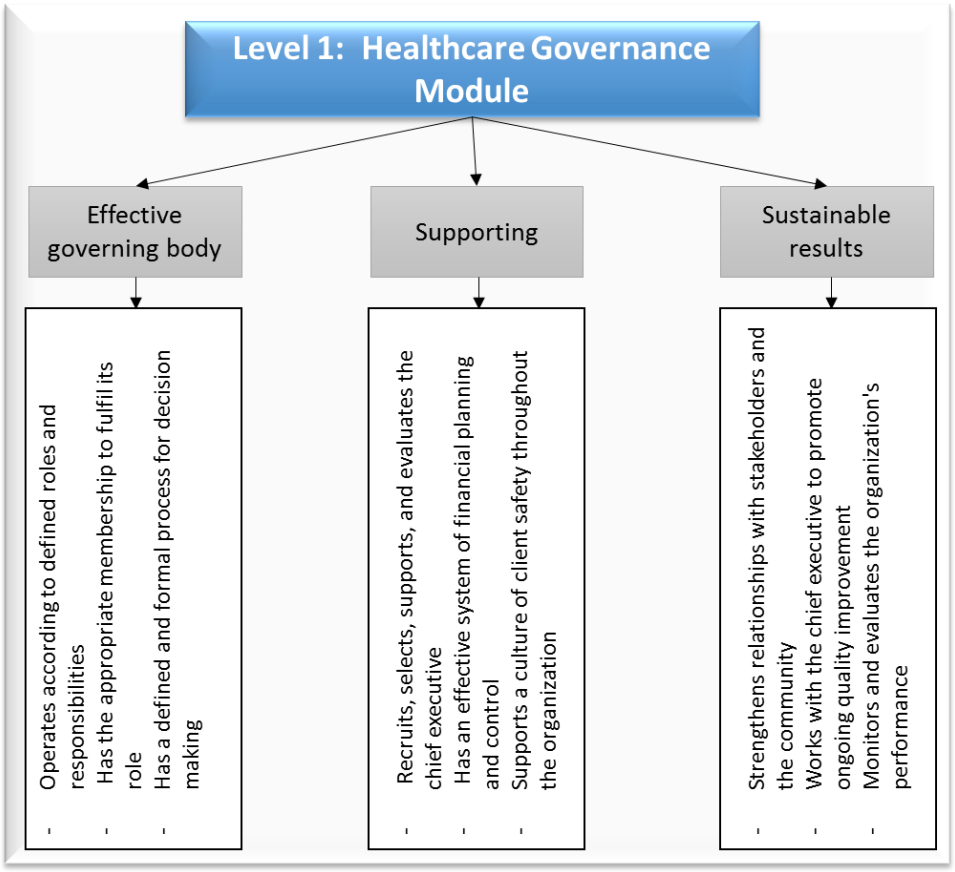


*Figure 4.6 IDEF0 Model for Healthcare Governance*

By comparing the level of *Healthcare Governance* with the system benchmark, the module will convert these information into recommendations about which aspects need to be improved in a prioritised manner.

### *4.3.1 Effective Governing Body*

The aim of this sub-module is to measure the governing body's effectiveness that represents the entrance of the organisation's governance module. It measures the governing body's roles and responsibilities, its membership and its process in decision-making as Figure 4.7 illustrates.

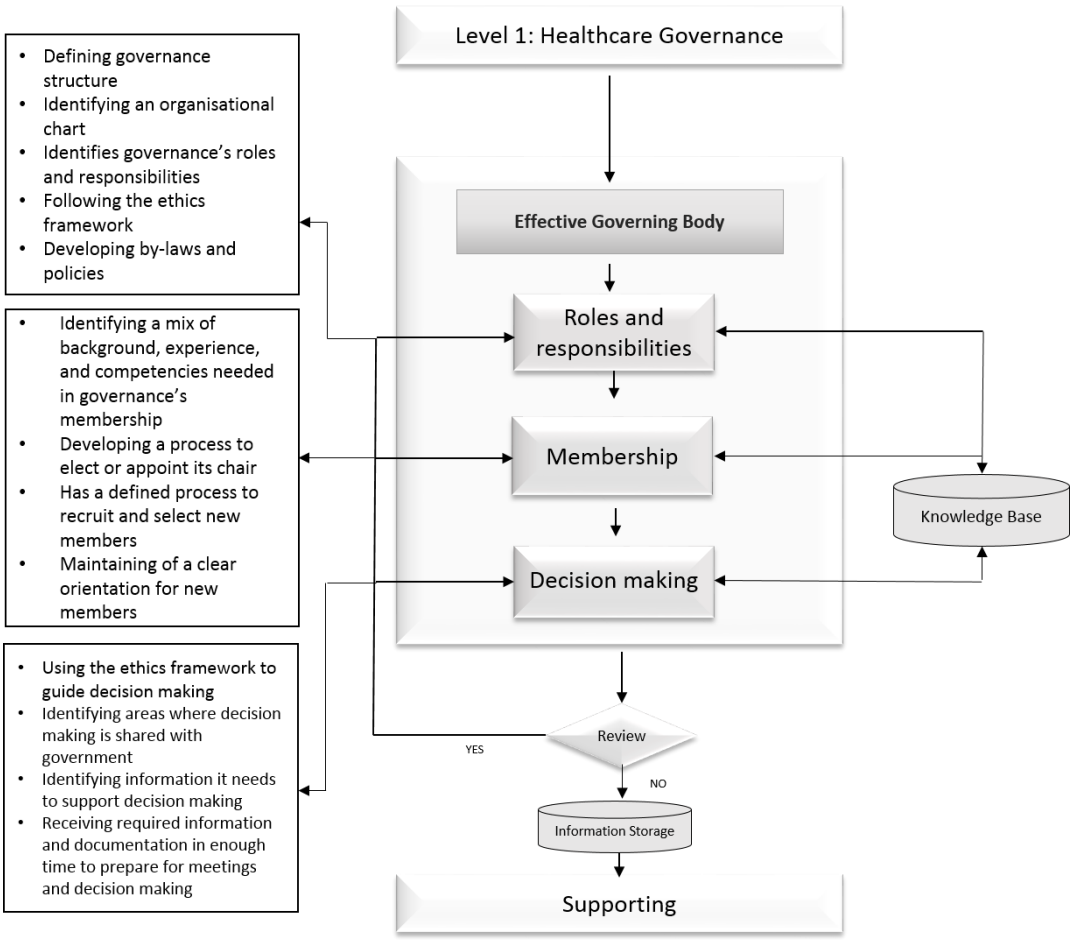


*Figure 4.7 Process flow chart of effective governing body sub-Module*

The following example of KB rules set is generated within the *effective governing body* sub-module:

**IF** *the organisation has a defined governance structure* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's governance structure is identified in an organisational chart* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body has written documentation that identifies its roles* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body has processes in place to oversee the functions of quality* (***Yes: GP; No: BP-PC-1)***

**AND** *the governing body has processes in place to oversee the functions of human resource management* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body updates its policies regularly* (***Yes: GP; No: BP-PC-1)***

**IF** *the governing body identifies the mix of experience needed in its membership to govern effectively* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body develops a process to appoint its chair (****Yes: GP; No: BP-PC-1)***

**AND** *the roles of the chair are described by-laws (****Yes: GP; No: BP-PC-3)***

**IF** *the governing body uses the ethics framework criteria to guide decision-making* ***(Yes: GP; No: BP-PC-3)***

**AND** *the governing body identifies areas where decision-making is shared with government* ***(Yes: GP; No: BP-PC-3)***

**AND** *the governing body receives required information in enough time to prepare for meetings* ***(Yes: GP; No: BP-PC-3)***

**AND** *the governing body reviews the type of information it receives to assess its appropriateness in helping the governing body to carry out its role* ***(Yes: GP; No: BP-PC-3)***

Based on the above KB rules, the system starts with asking the user if the organisation has a defined governance structure or not. The system has categorised the organisation as having a major problem with category PC-1, if it does not have a defined governance structure. This is also applicable to other KPIs that measure the governing body's effectiveness in the healthcare organisation, and this includes; identifying an organisational chart structure, availability of written documentation that identifies its roles, availability of processes in place to oversee the functions of quality and human resource, and updating its policies regularly.

In addition, the user will be asked if the governing body identifies the mix of experience needed in its membership or not. The system has categorised the organisation as having a major problem with category PC-1, if its body does not identify the mix of experience needed in its membership and does not develop a process to appoint its chair. The system has categorised the organisation as having a moderate problem with category PC-3, if the roles of the chair are not described by law, and if the governing body does not have a written criteria to recruit new members.

Furthermore, the user will be asked if the governing body uses the ethics framework criteria to guide decision-making or not. The system has categorised the organisation as having a moderate problem with category PC-3, if the governing body does not use the ethics framework criteria to guide decision-making. This is also applicable to other KPIs that measure the governing body's membership in the healthcare organisation, and this includes; identifying areas where decision-making is shared with government, receiving required information in enough time to prepare for meetings, and reviewing the type of information the governing body receives to assess its appropriateness in helping the governing body to carry out its role.

### *4.3.2 Supporting*

This sub-module aims to assess the governing body's support to planning, patient safety, and to its chief executive. Figure 4.8 illustrates that the assessment of *supporting sub-module* is based on the three following dimensions: evaluating the CEO, financial planning and supporting patient safety culture.

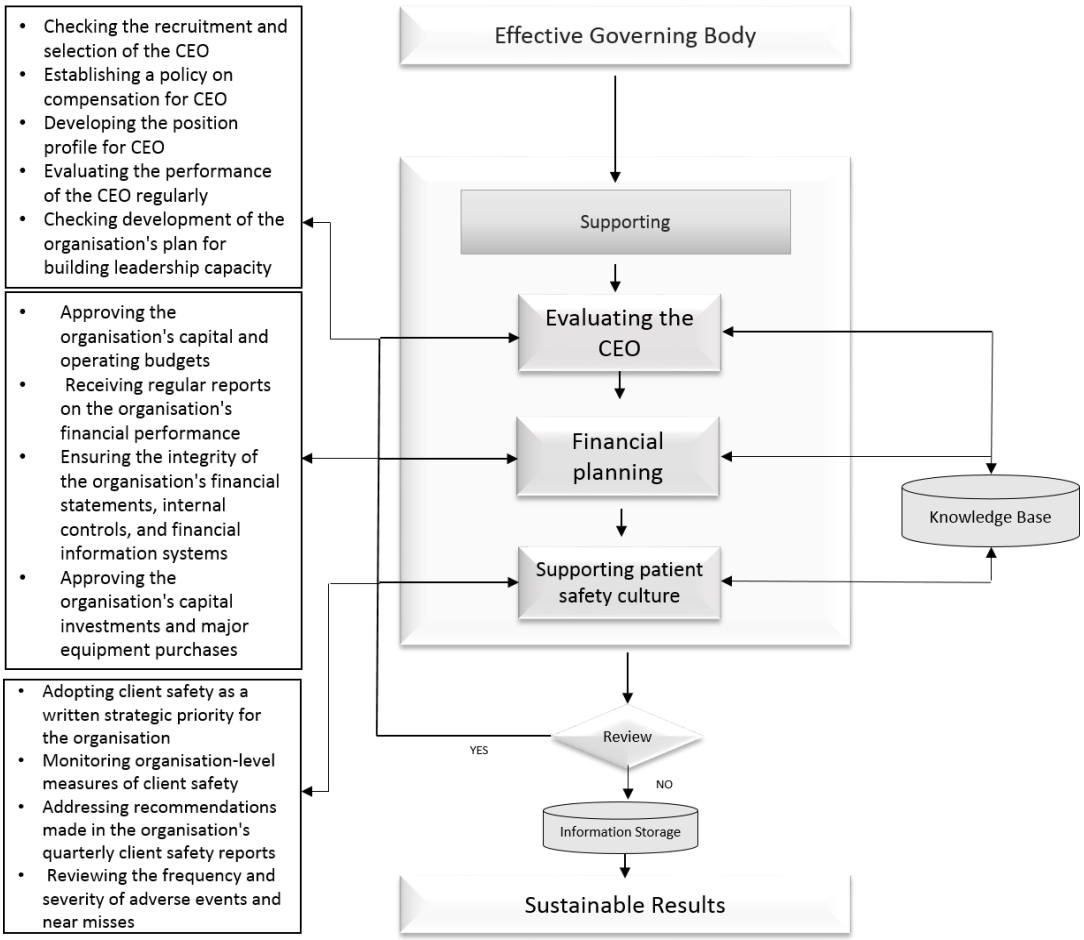


*Figure 4.8 Process flow chart of supporting sub-module*

The following example of KB rules set is generated within the *supporting* sub-module:

**IF** *the governing body oversees the recruitment of the chief executive* ***(Yes: GP; No: BP-PC-2)***

**AND** *the governing body establishes a policy on compensation for the chief executive* ***(Yes: GP; No: BP-PC-2)***

**AND** *the governing body sets performance objectives for the organisation's chief executive* ***(Yes: GP; No: BP-PC-2)***

**AND** *the governing body reviews the performance objectives for the organisation's chief executive annually* ***(Yes: GP; No: BP-PC-2)***

**AND** *the governing body has a succession plan for the chief executive* ***(Yes: GP; No: BP-PC-2)***

**IF** *the governing body approves the organisation's capital* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body approves the organisation's operating budgets* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body receives regular reports on the organisation's financial performance (**Yes: GP; No: BP-PC-2)***

**AND** *the governing body ensures the integrity of the organisation's financial statements **(Yes: GP; No: BP-PC-3)***

**AND** *the governing body reviews the organisation's capital investments **(Yes: GP; No: BP-PC-2)***

**AND** *the governing body addresses recommendations in financial reports in a timely way **(Yes: GP; No: BP-PC-2)***

**IF** *the governing body adopts client safety as a written strategic priority for the organisation **(Yes: GP; No: BP-PC-1)***

**AND** *the governing body monitors organisation-level measures of client safety **(Yes: GP; No: BP-PC-1)***

**AND** *the governing body addresses recommendations made in the organisation's quarterly client safety reports **(Yes: GP; No: BP-PC-1)***

**AND** *the governing body regularly reviews the frequency of adverse events **(Yes: GP; No: BP-PC-1)***

**AND** *the governing body regularly uses this information to understand client safety issues in the organisation **(Yes: GP; No: BP-PC-1)***

Based on the above KB rules, the system starts with asking the user if the governing body oversees the recruitment of the chief executive or not. The system has categorised the organisation as having a problem with category PC-2, if the governing body does not oversee the recruitment of the chief executive. This is also applicable to other KPIs that measure the governing body's supporting in the healthcare organisation such as; establishing a policy on compensation for the chief executive, setting performance objectives for the organisation's chief executive, and availability of a succession plan for the chief executive.

In addition, the user will be asked if the governing body approves the organisation's capital or not. The system has categorised the organisation as having a major problem with category PC-1, if the governing body does not approve the organisation's capital and operating budgets. The system has categorised the organisation

as having a problem with category PC-2, if the governing body does not receive regular reports on the organisation's financial performance, does not review the organisation's capital investments, and does not address recommendations in financial reports in a timely way. It is considered to be a moderate problem with category PC-3 in the organisation if the governing body does not ensure the integrity of the organisation's financial statements.

In the third dimension of this sub-module, the user will be asked if the governing body adopts client safety as a written strategic priority for the organisation or not. The system has categorised the organisation as having a major problem with category PC-1, if the governing body does not adopt client safety as a written strategic priority for the organisation. This is also applicable to other KPIs that measure the governing body's support to client safety culture in the healthcare organisation, and this includes; monitoring organisation-level measures of client safety, addressing recommendations made in the organisation's quarterly client safety reports, regularly reviewing the frequency of adverse events, and regularly using this information to understand client safety issues in the organisation.

Each sub-module with related dimensions is linked with the information base and benchmarked with the existing knowledge of the L6σ-QMHE standard through the KB database. The user feedback must be reviewed and verified at the end of the process.

### *4.3.3 Sustainable Results*

This sub-module aims to assess the sustainable results of the governing body in terms of its relations with community, promoting quality and patient safety, and evaluating performance. Figure 4.9 illustrates that the assessment of *sustainable results*

sub-module is based on the three following dimensions: relations with community, promoting quality and monitoring performance.

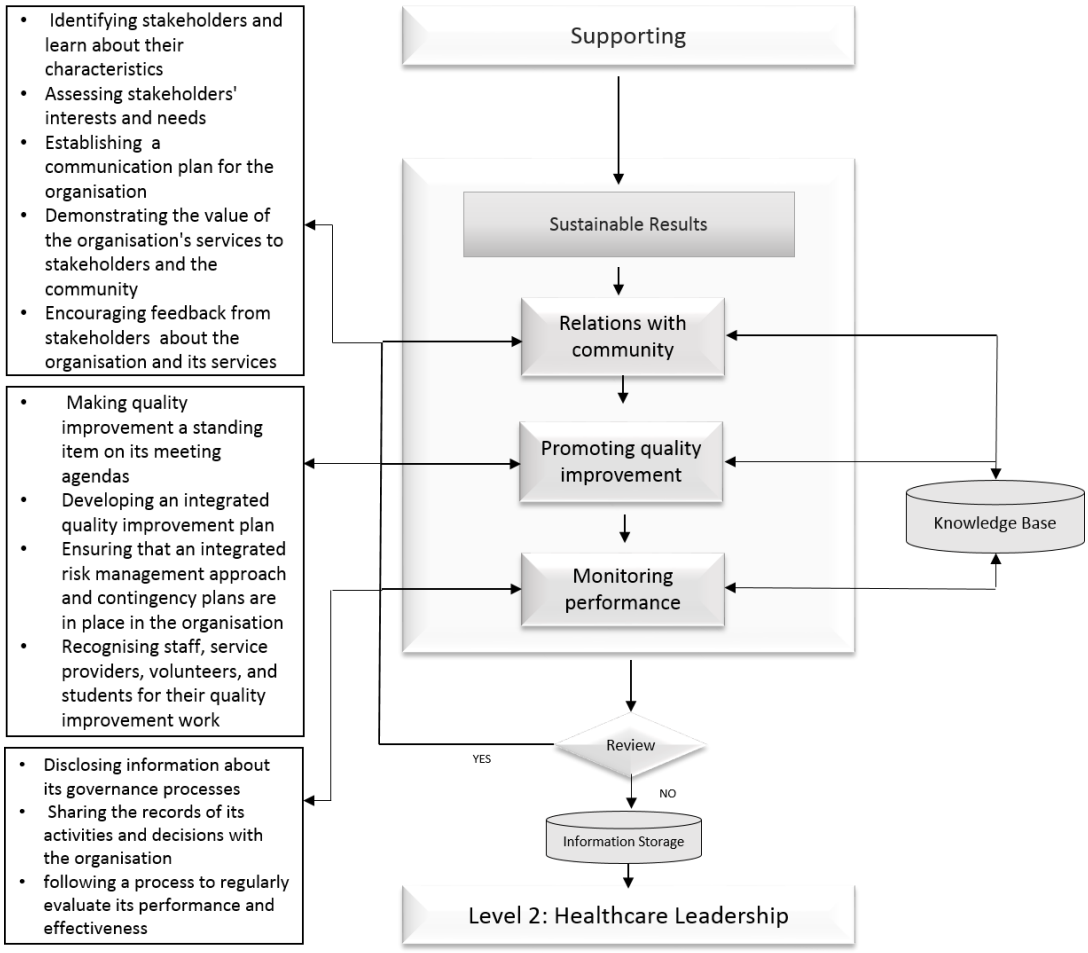


*Figure 4.9 Process flow chart of sustainable results sub-module*

The following example of KB rules set is generated within the *sustainable results* sub-module:

**IF** *the governing body works with the chief executive to identify stakeholders* ***(Yes: GP; No: BP-PC-3)***

**AND** *the governing body assesses stakeholders' interests in consultation with the chief executive* ***(Yes: GP; No: BP-PC-3)***

**AND** *the governing body ensures that information is communicated with other organisations according to the communication plan* ***(Yes: GP; No: BP-PC-3)***

**AND** *the governing body regularly consults with and encourages feedback from the community about the organisation and its services* ***(Yes: GP; No: BP-PC-3)***

**IF** *the governing body makes quality improvement a standing item on its meeting agendas* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body works with the chief executive to develop an integrated quality improvement plan (****Yes: GP; No: BP-PC-2)***

**AND** *the governing body ensures that risk management approach plans are in place in the organisation (****Yes: GP; No: BP-PC-2)***

**AND** *the governing body monitors input into the organisation's strategies to address client flow in service demands* ***(Yes: GP; No: BP-PC-2)***

**AND** *the governing body promotes learning from results for the organisation* ***(Yes: GP; No: BP-PC-2)***

**AND** *the governing body demonstrates a commitment to recognising staff for their quality improvement work* ***(Yes: GP; No: BP-PC-2)***

**IF** *the governing body identifies the data and information it needs to monitor the organisation's performance* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body monitors data to assess the achievement of the strategic plan* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body monitors the actions taken to address opportunities* ***(Yes: GP; No: BP-PC-1)***

**AND** *the governing body follows a process to regularly evaluate its performance* ***(Yes: GP; No: BP-PC-2)***

**AND** *the governing body prepares an annual report of its achievements* ***(Yes: GP; No: BP-PC-1)***

Based on the above KB rules, the system starts with asking the user if the governing body works with the chief executive to identify stakeholders or not. The system has categorised the organisation as having a moderate problem with category PC-3, if the governing body does not work with the chief executive to identify stakeholders. This is also applicable to other KPIs that measure the sustainable results of the governing body in the healthcare organisation, and this includes; assessing stakeholders' interests in consultations with the chief executive, ensuring that information is communicated with other organisations according to the communication plan, and regularly consulting with and encouraging feedback from the community about the organisation and its services.

Then, the user will be asked if the governing body makes quality improvement a standing item on its meeting's agenda or not. The system has categorised the organisation as having a major problem with category PC-1, if the governing body does not make quality improvement a standing item on its meeting's agenda. The system has categorised the organisation as having a problem with category PC-2, if the governing body does not work with the chief executive to develop an integrated quality improvement plan, does not ensure that risk management approach plans are in place in the organisation and does not monitor input into the organisation's strategies to address client flow in service demands. It is also considered to be a problem with category PC-2 in the organisation if the governing body does not promote learning from results for the organisation, and does not show a commitment to recognise its staff for their quality improvement work.

In the third dimension of this sub-module, the user will be asked if the governing body identifies the data and information it needs to monitor the organisation's performance or not. The system has categorised the organisation as having a major problem with category PC-1, if the governing body does not identify the data and information it needs to monitor the organisation's performance. This is also applicable to other KPIs that monitor the healthcare organisation's performance, and this includes; monitoring data to assess the achievement of the strategic plan, monitoring the actions taken to address opportunities and preparing an annual report of its achievements. It is considered to be a problem with category PC-2 in the organisation if the governing body does not follow a process to regularly evaluate its performance.

### 4.4 Level 2: Healthcare Leadership

The *Healthcare Leadership* is the third module that needs to be studied. This level helps to capture data about the organisation's leaders and how they plan for quality and disasters. It also helps to measure the leadership efforts to form a caring culture among

the organisation. The user will be at the beginning asked some questions that will decide whether the organisation's leaders are creating a caring culture or not. Then, the system will examine the planning and designing process to make sure if it is satisfying the needs of the community, respond to its changes, and implementing an operational plan to do that.

Moreover, the user will be asked questions regarding the preparedness of organisation for emergencies and disasters. The improvement of quality is the next part under this module. In this part the user will be asked about the risk managing process in the organisation, improving patient safety and developing a QM system. The rules developed in the module will establish relationships, converting that data into information. *Level 2* can be illustrated in the model diagram shown in Figure 4.10.

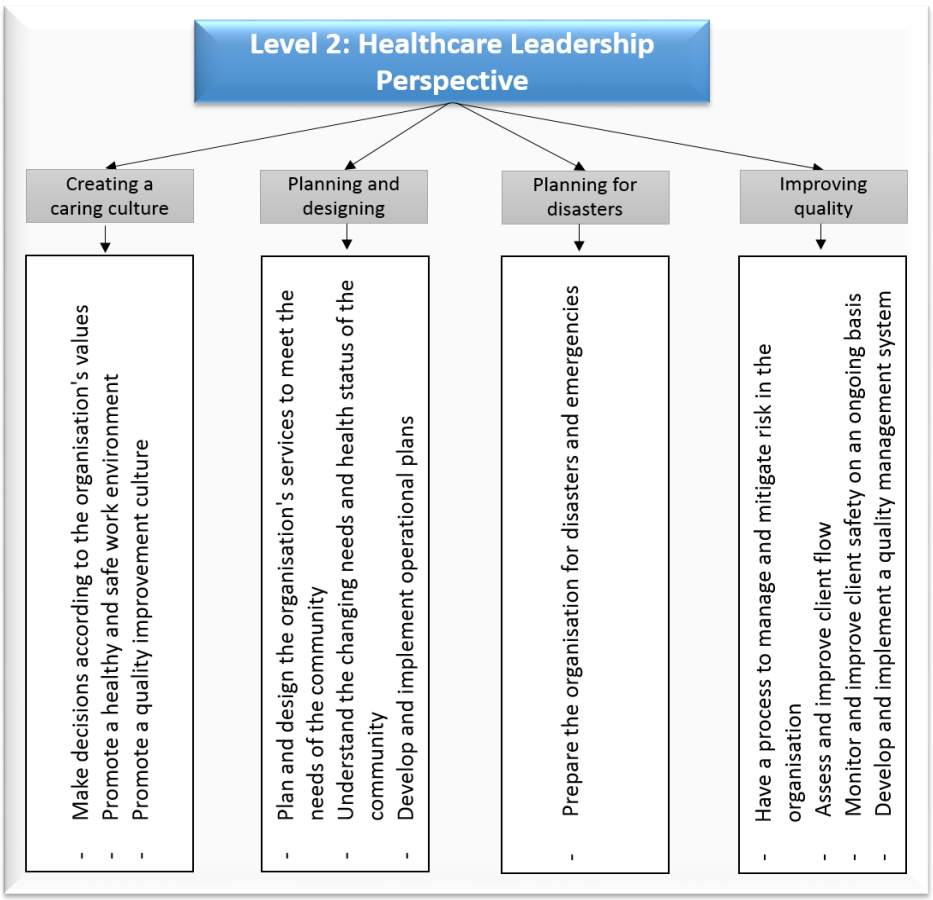


*Figure 4.1 IDEF0 Model for Healthcare Leadership*

By comparing the level of *Healthcare Leadership* with the system benchmark, the module will convert these information into recommendations about which aspects need to be improved in a prioritised manner.

### *4.4.1 Creating a caring culture*

The aim of this sub-module is to measure the healthcare leadership effectiveness in promoting and maintaining the caring culture in the healthcare environment. It examines if the decisions are taken according to the organisation's values or not. Furthermore, it assesses how the leadership is promoting a safe work environment and quality culture.

Figure 4.11 illustrates that the assessment of *creating a caring culture* based on three dimensions; decisions according to values, promoting a safe working environment, and promoting a quality culture.

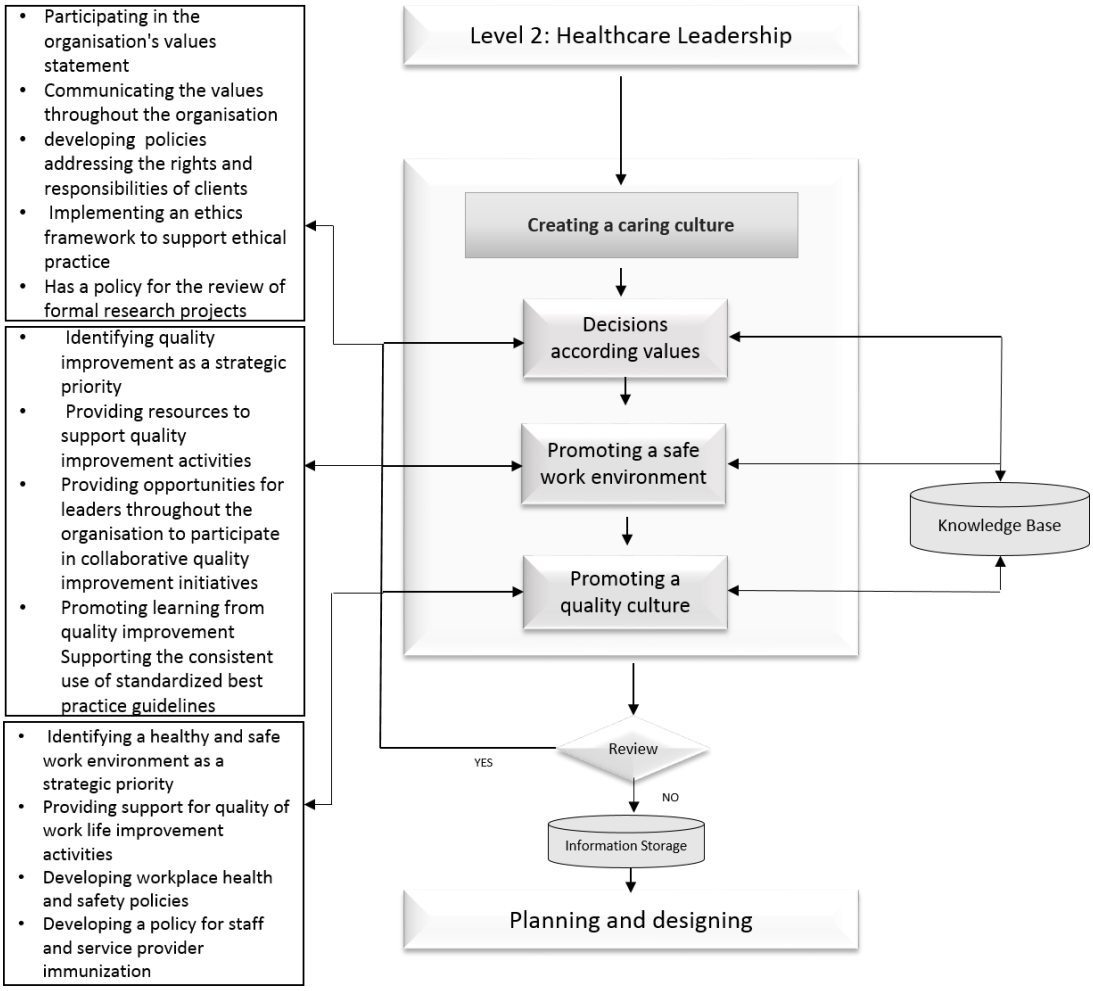


*Figure 4.2 Process Flow Chart of creating a caring culture Sub-Module*

The following example of KB rules set is generated within the *creating a caring culture* sub-module:

**IF** *the organisation's leaders participate in defining the organisation's values statement* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders communicate the values throughout the organisation* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders develop policies addressing the rights of clients* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders implement policies addressing the rights of clients (****Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders have a process for reviewing information about trends in ethics issues (****Yes: GP; No: BP-PC-4)***

**IF** *the organisation's leaders identify a healthy work environment as a strategic priority* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders monitor outcome measures related to the work environment* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders provide support for quality of work life improvement activities* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

**AND** *the organisation's leaders develop workplace safety policies that comply with relevant legislation* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

**AND** *the organisation's leaders monitor staff stress levels* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

**IF** *the organisation's leaders identify quality improvement as a strategic priority* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders have a process for reviewing information about trends in ethics issues (****Yes: GP; No: BP-PC-4)***

**AND** *the organisation's leaders support the sustainability of quality improvement results* ***(Yes: GP; No: BP-PC-4)***

**AND** *the organisation's leaders promote learning from quality improvement result by patient experience* ***(Yes: GP; No: BP-PC-4)***

**AND** *the organisation's leaders provide opportunities for leaders throughout the organisation to participate in collaborative quality improvement initiatives* ***(Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders provide resources to support quality improvement activities* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

Based on the above KB rules, the system starts with asking the user if the organisation's leaders participate in defining the organisation's value statement or not. The system has categorised the organisation as having a major problem with category PC-1,

if its leaders do not participate in defining the organisation's value statement. The system has categorised the organisation as having a problem with category PC-2, if the organisation's leaders do not communicate the values throughout the organisation, do not develop policies addressing the rights of clients and do not implement policies addressing the rights of clients. If the organisation's leaders do not have a process for reviewing information about trends in ethics issues, the system considers it as a minor problem with PC-4.

Then, the user will be asked if the organisation's leaders identify a healthy work environment as a strategic priority or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not identify a healthy work environment as a strategic priority and if they do not monitor outcome measures related to the work environment in the organisation. The system has provided the user five options to answer the next three questions starting from very good which is considered to be a GP and ending with very poor which is considered to be a major problem with PC-1. The user can select the suitable option based on the current practise in his/her organisation. These questions are about providing support for quality of work, life improvement activities, developing workplace safety policies and monitoring staff stress levels.

In the third dimension of this sub-module, the user will be asked if the organisation's leaders identify quality improvement as a strategic priority or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not identify quality improvement as a strategic priority. It is considered to be a minor problem with category PC-4 in the organisation if the leaders do not have a process for reviewing information about trends in ethics issues, do not support the

sustainability of quality improvement results, and do not promote learning from quality improvement result by patient experience.

The system has categorised the organisation as having a moderate problem with category PC-3 if the leaders do not provide opportunities for mid-level leaders throughout the organisation to participate in collaborative quality improvement initiatives. Finally, the system has examined if the healthcare leaders provide resources to support quality improvement activities. The good point (GP) for this question is valid only if the user has answered the question with Very Good (Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1).

### *4.4.2 Planning and designing*

This sub-module aims to assess the healthcare leadership efficiency in planning and designing. It examines if the healthcare leaders plan for the community requirements or not. Likewise, it assesses how the leadership is working to understand the change in relation to these requirements, and how they are developing and implementing their operational plans.

Figure 4.12 illustrates the assessment of *planning and designing* based on three dimensions; planning for community needs, understanding community health status needs, and developing operational plans.

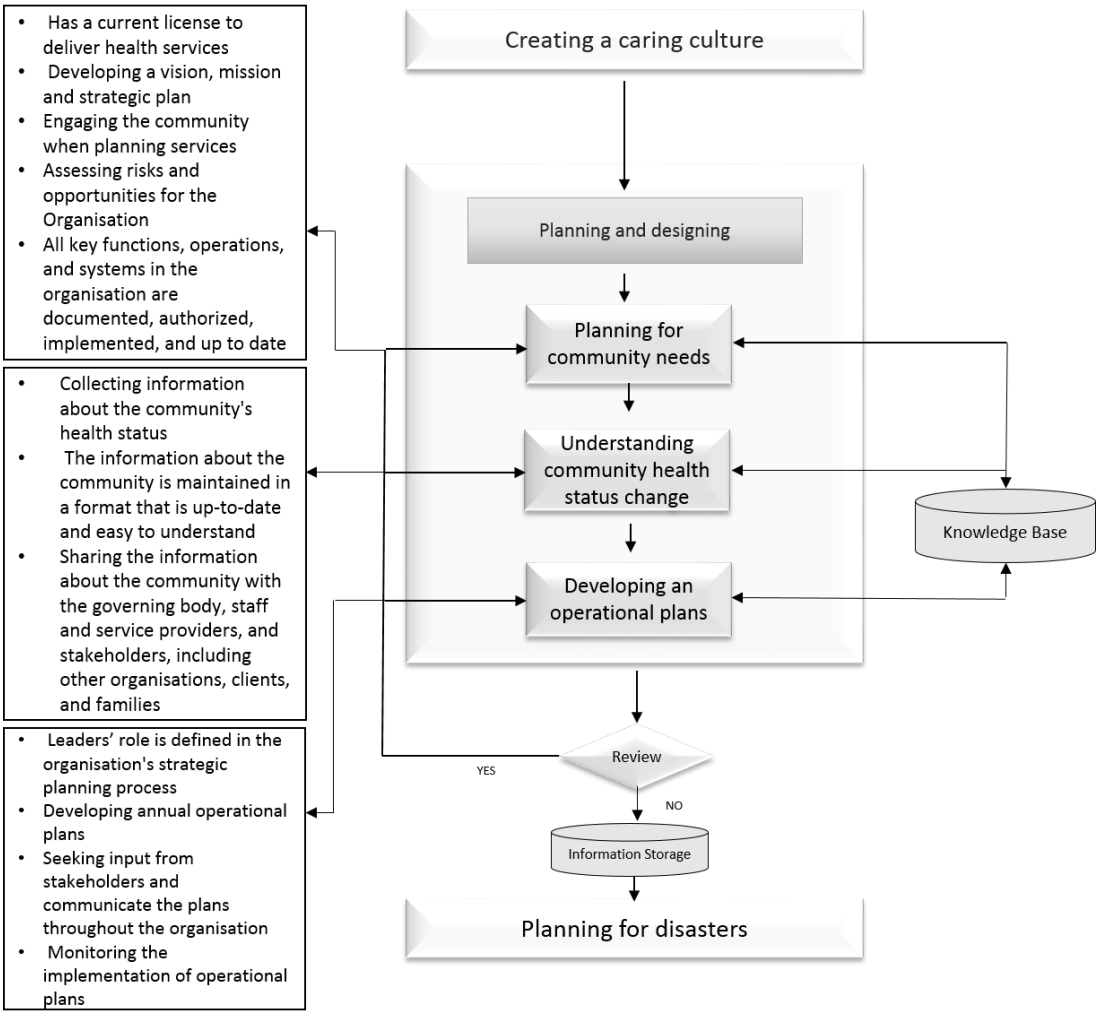


*Figure 4.3 Process flow chart of planning and designing sub-module*

The following example of KB set of rules is produced within the *planning and designing* sub-module:

**IF** *the organisation's leaders collect information about the community's health status needs* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's information about the community is maintained in a format that is up-to-date* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders have access to information about the community's health capacities needs* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders share the information about the community with clients' families* ***(Yes: GP; No: BP-PC-3)***

**IF** *the organisation has a current license to deliver health services* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's strategic plan includes goals that have measurable outcomes* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders participate in a process to develop the mission statement* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders share the vision with staff (**Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders report on the organisation's progress toward achieving the objectives to internal stakeholders (**Yes: GP; No: BP-PC-3)***

**IF** *the organisation's leaders define their role in the organisation's strategic planning process* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders develop annual operational plans to support the achievement of the strategic plan (**Yes: GP; No: BP-PC-2)***

**AND** *when developing the operational plans, the organisation's leaders seek input from service providers* ***(Yes: GP; No: BP-PC-3)***

**AND** *the operational plans identify the resources needed to deliver services* ***(Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders develop a process to manage change* ***(Yes: GP; No: BP-PC-4)***

Based on the above KB rules, the system starts with asking the user if the organisation's leaders collect information about the community's health status needs or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not collect information about the community's health status needs. The system has categorised the organisation as having a problem with category PC-2, if its information about the community is not maintained in a format that is up-to-date and if its leaders do not have access to information about the community's health capacity needs. If the organisation's leaders do not share the information about the community with families of clients, the system considers it as a moderate problem with PC3.

In the next dimension, the user will be asked if the organisation has a current license to deliver health services or not. The system has categorised the organisation as having a major problem with category PC-1, if it does not have a current license to deliver

health services and if its strategic plan does not include goals that have measurable outcomes. The system has characterised the organisation as having a problem with category PC-2, if its leaders do not participate in a process to develop its mission statement. The organisation is considered to have a moderate problem category PC-3 if its leaders do not share the vision with staff, and do not report on the organisation's progress toward achieving the objectives to internal stakeholders.

In the third dimension of this sub-module, the user will be asked if the organisation's leaders define their role in the organisation's strategic planning process or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not define their role in the organisation's strategic planning process. The system has categorised the organisation as having a moderate problem with category PC-3 if its leaders do not seek input from service providers when developing the operational plans and if its operational plans do not identify the resources needed to deliver services. It is considered to be a minor problem with category PC-4 in the organisation if its leaders do not develop a process to manage change.

### *4.4.3 Planning for disasters*

The aim of this sub-module is to assess the healthcare organisation’s planning for disaster and emergencies. It examines if the healthcare leaders develop, implement, and evaluate an all hazard, disaster, and emergency response. It also, measures how the leadership is working to provide access to education to support an all hazard, disaster, and emergency response.

Figure 4.13 illustrates that the assessment of *planning for disaster* based on preparing for disaster and emergencies dimension.

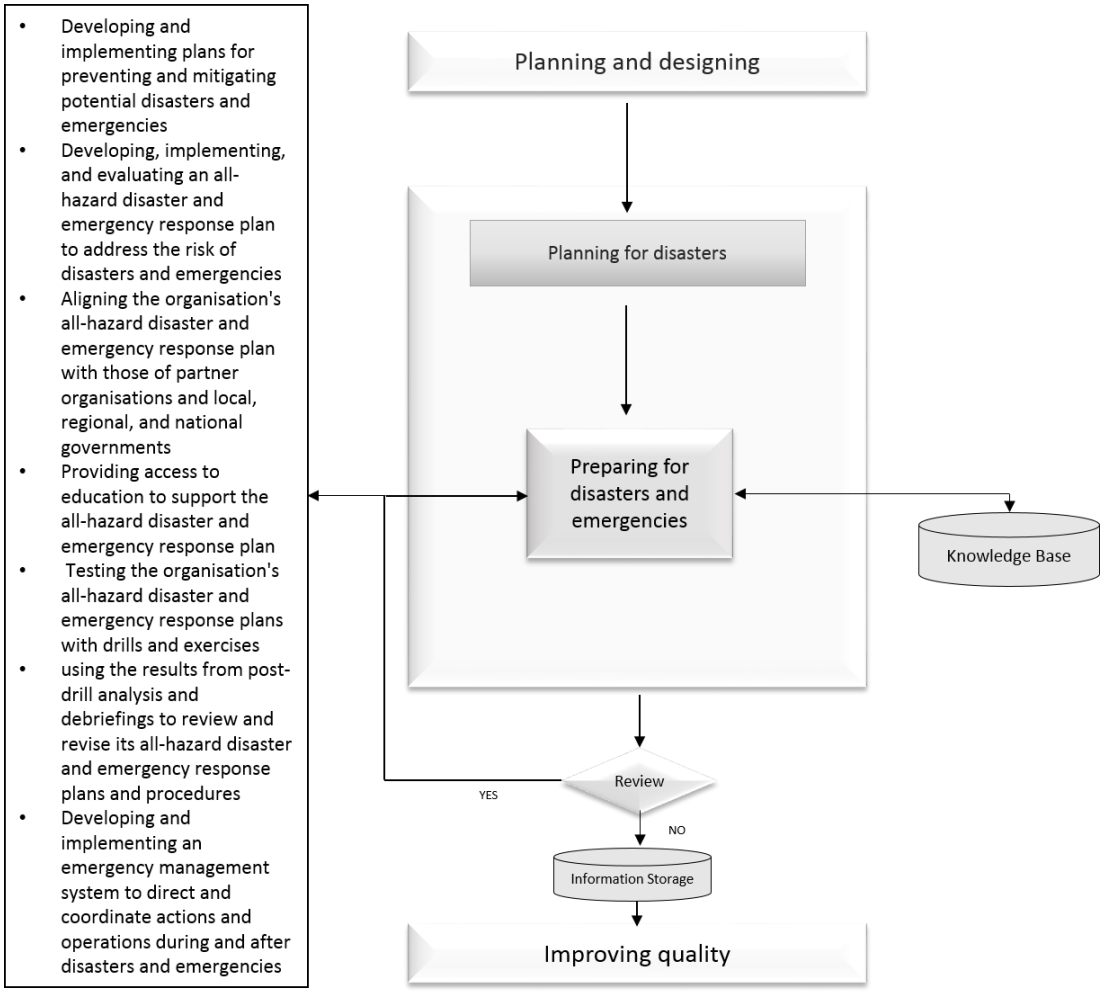


*Figure 4.4 Process flow chart of the planning for disaster sub-module*

The following example of KB set of rules is produced within the *planning for disaster* sub-module:

**IF** *the organisation's leaders develop plans for preventing potential disasters (**Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders develop an all-hazard, disaster, and emergency response plan to address the risk of disasters and emergencies **(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders align the organisation's all-hazard, disaster, and emergency response plan with those of partner organisations **(Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders regularly test the organisation's all-hazard, disaster, and emergency response plans with drills and exercises to evaluate the state of response preparedness **(Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders implement an emergency management system to direct actions and operations during disasters and emergencies* ***(Yes: GP; No: BP-PC-3)***

Based on the above KB rules, the system starts with asking the user if the organisation's leaders develop plans for preventing potential disasters or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not develop plans for preventing potential disasters. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not develop an all-hazard, disaster, and emergency response plan to address the risk of disasters and emergencies. If the organisation's leaders do not align the organisation's all-hazard, disaster, and emergency response plan with those of partner organisations, the system considers it as a moderate problem with PC3. This is also applicable if the organisation's leaders do not test the organisation's all-hazard, disaster, and emergency response plans with drills and do not implement an emergency management system during disasters and emergencies.

### *4.4.4 Improving quality*

The aim of this sub-module is to measure the healthcare leadership's ability to identify and enhance patient safety. It aims also to optimise and evaluate the client flow strategy. Likewise, it assesses how the QM system is developed and implemented. Figure 4.14 illustrates the assessment of *improving quality* based on four dimensions; managing risk, improving client flow, improving client safety, and implementing a QM system.

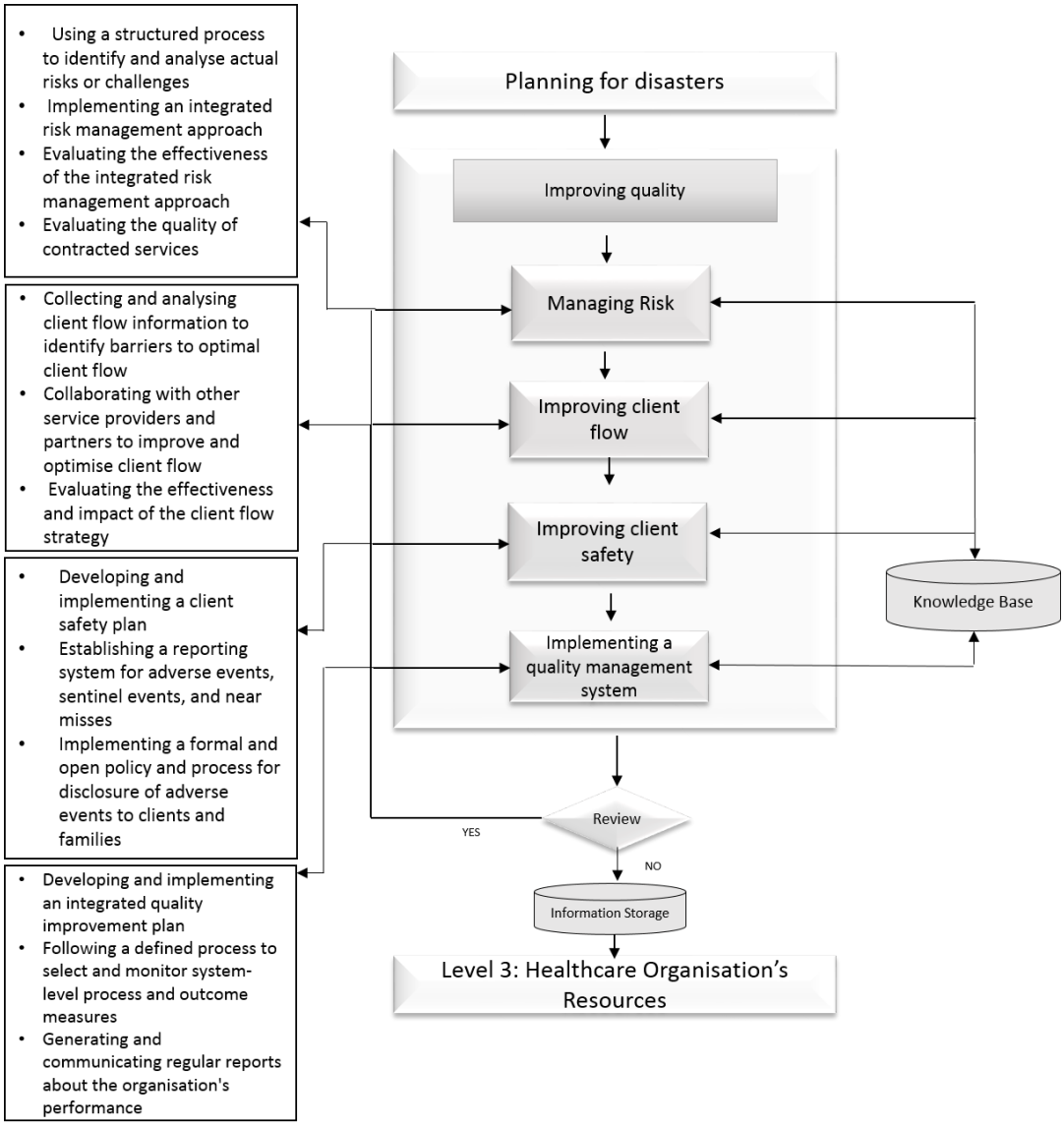


*Figure 4.5 Process flow chart of the improving quality sub-module*

The following example of KB set of rules is generated within the *improving quality* sub-module:

**IF** *the organisation's leaders use a structured process to identify actual risks* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders implement an integrated risk management approach to mitigate risk* ***(Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders evaluate the effectiveness of the integrated risk management approach* ***(Yes: GP; No: BP-PC-3)***

**IF** *the organisation's leaders collect client flow information to identify barriers to optimal client flow* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation evaluates the effectiveness of the client flow strategy* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders use information about barriers to client flow in order to develop a strategy of building the organisation's strategy* ***(Yes: GP; No: BP-PC-3)***

**IF** *the organisation develops a client safety plan* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation establishes a reporting system for sentinel events including appropriate follow-up* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation implements a formal and open policy, and process for disclosure of adverse events to clients* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation monitors its client safety culture by using the Hospital Survey on Patient Safety Culture Instrument (****Yes: GP; No: BP-PC-3)***

**IF** *the organisation's leaders develop an integrated quality improvement plan* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders follow a defined process to select system-level process and outcome measures* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

**AND** *the organisation's leaders communicate the results of quality improvement activities broadly* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1***

Built on the above KB rules, the system starts with asking the user if the organisation's leaders use a structured process to identify risks or not. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not use a structured process to identify risks. The system has categorised the organisation as having a problem with category PC-3, if its leaders do not implement an integrated risk management approach to mitigate risk, and do not evaluate the effectiveness of that approach.

In the next dimension, the user will be asked if the organisation's leader collect client flow information to identify barriers for optimal client flow or not. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not collect client flow information and do not evaluate the effectiveness of the client flow

strategy. The organisation considered to have a moderate problem category PC-3 if its leaders do not use information about barriers to client flow to build the organisation's capacity to meet the demand for service.

In patient safety dimension, the user will be asked if the organisation develops a client safety plan or not. The system has categorised the organisation as having a major problem with category PC-1, if it does not develop a client safety plan. It has categorised the organisation as having a problem with category PC-2, if it does not establish a reporting system for sentinel events including appropriate follow-up and does not monitor its client safety culture by using the Hospital Survey on Patient Safety Culture Instrument.

In quality management system dimension, the user will be asked if the organisation's leaders develop an integrated quality improvement plan or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not develop an integrated quality improvement plan. It has examined if the healthcare leaders follow a defined process to select system-level process and outcome measures. The good point (GP) for this question is valid only if the user has answered the question with Very Good (Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1). This assessment is also used to judge if the organisation's leaders communicate the results of quality improvement activities broadly or not.

### 4.5 Level 3: Healthcare Organisation's Resources

Moving to the next level, *Healthcare Organisation's Resources* is the fourth module that needs to be examined. This level helps to capture data about the organisation's human resource status. It also helps to measure the financial efficiency and the physical environment of the healthcare organisation. The user will be at the

beginning asked some questions that will decide whether the organisation has enough number human resources and enough training and labor cost resources.

Then, the system will examine the physical capital of the organisation to make sure if it has enough resources for investment in buildings and equipment, and promoting maintenance. After that, the system will inspect other resources such as; hospital information system. The rules developed in the module will establish relationships, converting that data into information. *Level 3* can be illustrated in the model diagram and shown in Figure 4.15.

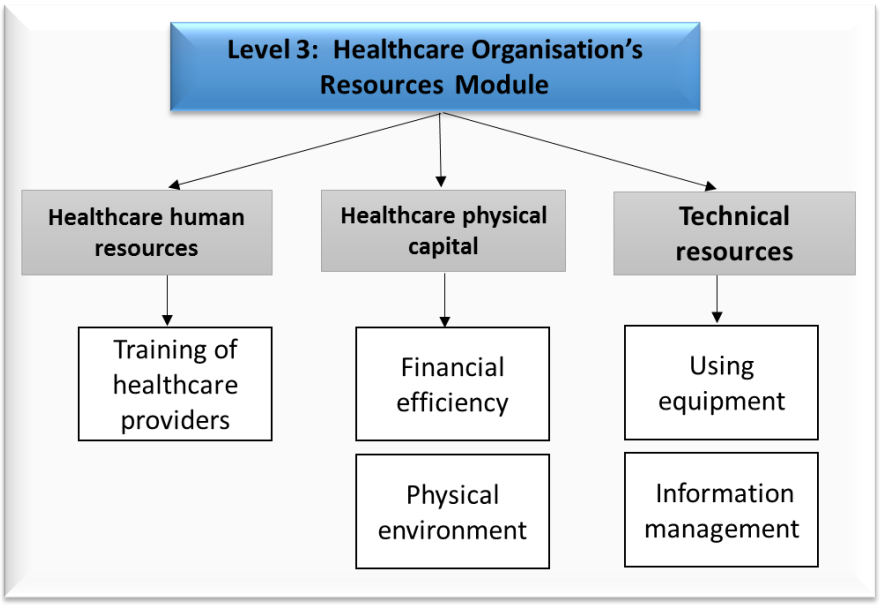


*Figure 4.6 IDEF0 Model for Healthcare Organisation's Resources*

By comparing the level of *Healthcare Organisation's Resources* with the system benchmark, the module will convert that information into recommendations about which aspects need to be improved in a prioritised manner.

### *4.5.1 Human resources*

The aim of this sub-module is to assess the healthcare leadership's ability to develop and implement recruiting and retention strategies for the staff in the organisation. It aims also to define roles and responsibilities for client safety. Likewise, it assesses how the staff performance is monitored and evaluated.

Figure 4.16 illustrates the assessment of *human resources* based on the dimension of *training of healthcare providers.*

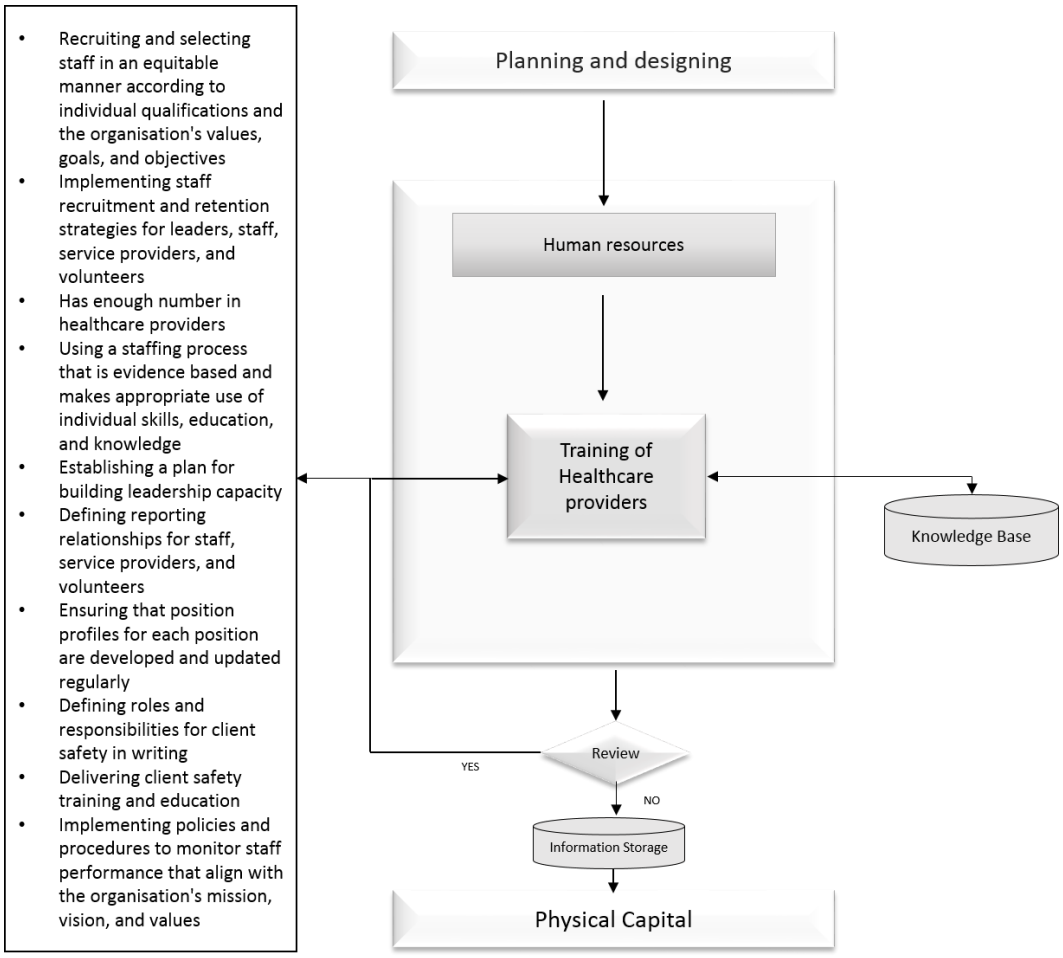


*Figure 4.7 Process Flow Chart of the Human resources Sub-Module*

The following example of KB set of rules is produced within the *human resources* sub-module:

**IF** *the organisation's leaders recruit and select staff in an equitable manner according to individual qualifications* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders define reporting relationships for staff* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

**AND** *the organisation delivers client safety training and education at least annually to the organisation's leaders including education targeted to specific client safety focus areas* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

**AND** *the organisation delivers annual training and education on patient safety* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1****)*

**AND** *the organisation's leaders develop a process for maintaining and storing human resource records for staff members in a manner that protects individual privacy* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

Based on the above KB rules, the system starts with asking the user if the organisation's leaders recruit and select staff in an equitable manner according to individual qualifications or not. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not recruit and select staff in an equitable manner according to individual qualifications. The system has examined if the healthcare leaders define reporting relationships for staff. The good point (GP) for this question is valid only if the user has answered the question with Very Good (Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1). This assessment is also used to judge if the organisation deliver client safety training and education at least annually to its leaders and staff or not. Likewise, the same scale is used to measure if the organisation's leaders develop a process for maintaining and storing human resource records for members of staff in a manner that protects individual privacy.

### *4.5.2 Physical Capital*

This sub-module aims to assess the effectiveness of financial resources allocation decisions and budget monitoring in the organisation. Its objective is to also optimise and evaluate the physical space of each department in the organisation. Likewise, it assesses client and staff health, as well as safety at all times.

Figure 4.17 illustrates that the assessment of *physical capital* sub-module is based on the two following dimensions: financial efficiency and physical environment.

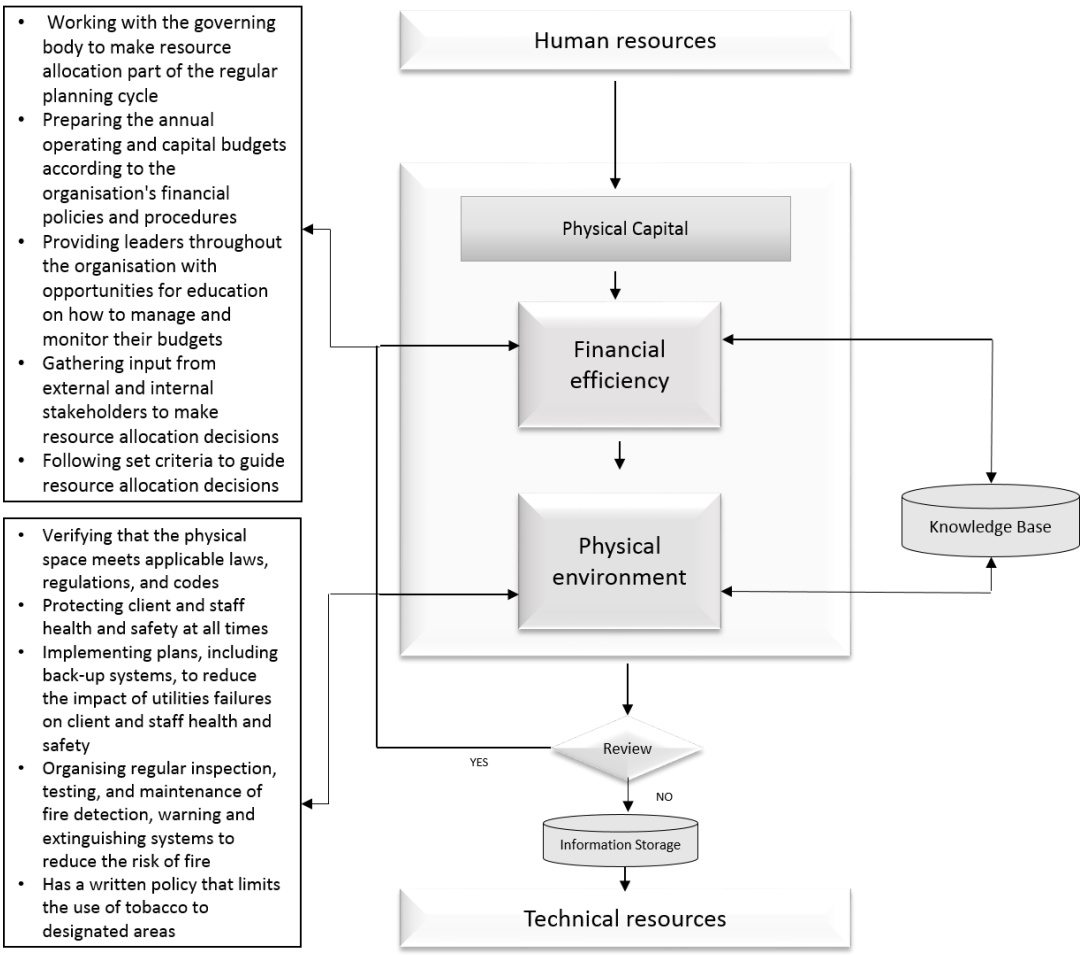


*Figure 4.8 Process flow chart of the physical capital sub-module*

The following example of KB set of rules is made within the *physical capital* sub-module:

**IF** *the organisation's leaders prepare the annual capital budget according to the organisation's financial policies and procedures* ***(Yes: GP; No: BP-PC-1)***

**AND** *the organisation's leaders, working with the governing body where applicable, make resource allocation part of the regular planning cycle* ***(Yes: GP; No: BP-PC-2***

**AND** *the organisation's leaders provide mid-level leaders throughout the organisation with opportunities for education on how to manage their budgets* ***(Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders have the annual operating budget approved by the governing body* ***(Yes: GP; No: BP-PC-3)***

**IF** *the organisation's leaders verify and ensure that the physical space meets applicable laws* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders protect staff health and safety at all times and particularly during periods of construction* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation regularly tests its water sources to document its quality (****Yes: GP; No: BP-PC-2)***

**AND** *all of the organisation's emergency exit routes are clearly marked (****Yes: GP; No: BP-PC-4)***

Based on the above KB rules, the system starts with asking the user if the organisation's leaders prepare the annual capital budget according to the organisation's financial policies and procedures or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not prepare the annual capital budget according to the organisation's financial policies and procedures. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not working with the governing body to make resource allocation as part of the regular planning cycle. If the organisation's leaders do not provide mid-level leaders throughout the organisation with opportunities for education on how to manage their budgets and if they do not have the annual operating budget approved by the governing body, the system considers that as a moderate problem with PC-3.

In the second dimension, the user will be asked if the organisation's leaders verify and ensure the physical space meets applicable laws or not. The system has categorised the organisation as having a major problem with category PC-1, if its leaders do not verify and ensure the physical space meets applicable laws. This is also applicable to other KPIs that measure if the organisation's leaders protect staff health and safety at all times and if it tests its water sources regularly to document its quality. The organisation is considered to have a minor problem category PC-4 if all of the organisation's emergency exit routes are not clearly marked.

### *4.5.3 Technical Resources*

The aim of this sub-module is to measure the healthcare leadership's ability to select and buy medical devices and equipment. Moreover, it aims to evaluate the process for maintaining, upgrading and replacing medical devices. It also, assess the process of selecting and implementing information management system in the organisation.

Figure 4.18 illustrates the assessment of *technical resources* based on two dimensions; *using equipment and information management.*

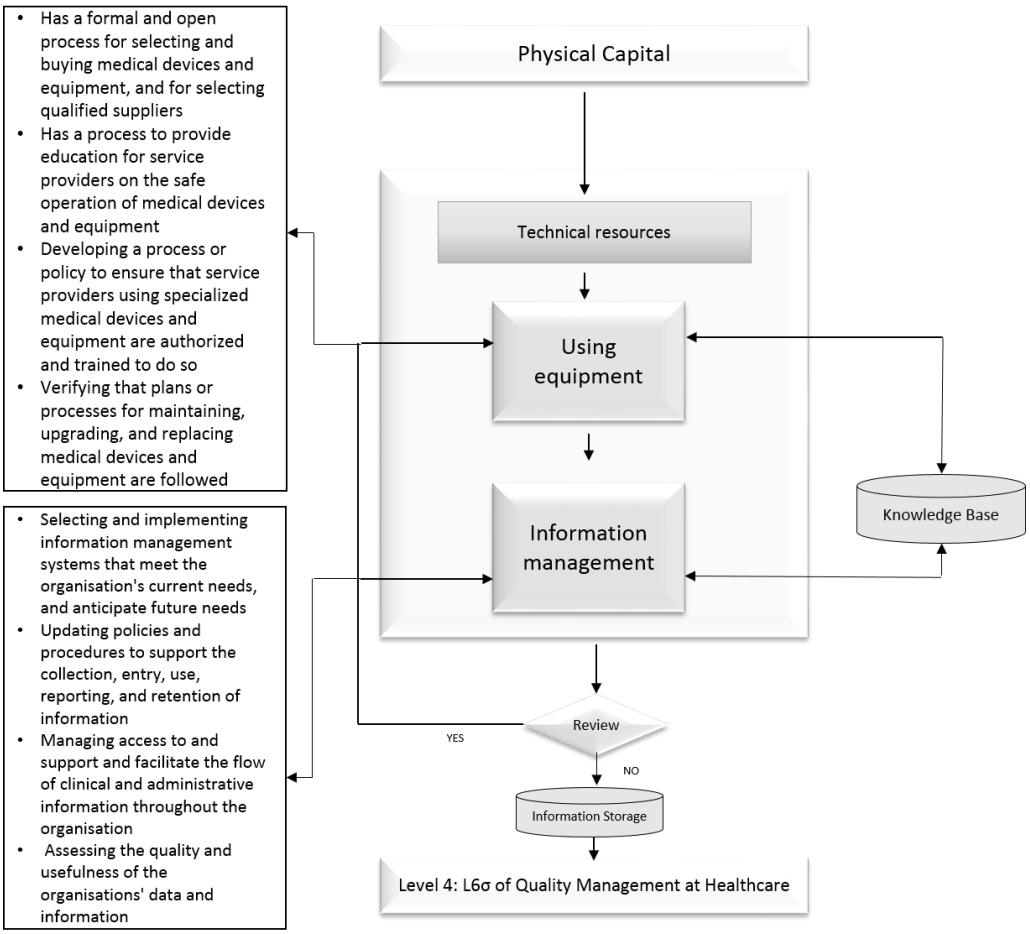


*Figure 4.9 Process flow chart of the technical resources sub-module*

The following example of KB set of rules is produced within the *technical resource* sub-module:

**IF** *the organisation's leaders have a formal and open process for selecting medical devices* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders develop a process or policy to ensure that service providers use specialized medical devices* ***(Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders have a process to evaluate the effectiveness of the preventive maintenance program (**Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders implement an effective preventive maintenance program for medical devices* ***(Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1)***

**IF** *the organisation's leaders implement policies and procedures to support the collection of information* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders provide staff with timely access to research, evidence, and best practice information* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders regularly improve the organisation's information systems* ***(Yes: GP; No: BP-PC-2)***

**AND** *the organisation's leaders support and facilitate the flow of administrative information throughout the organisation* ***(Yes: GP; No: BP-PC-3)***

Based on the above KB rules, the system starts with asking the user if the organisation's leaders have a formal and open process for selecting medical devices or not. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not have a formal and open process for selecting medical devices. The system has categorised the organisation as having a moderate problem with category PC-3, if its leaders do not develop a process or policy to ensure that service providers use specialized medical devices and do not have a process to evaluate the effectiveness of the preventive maintenance program. The system has examined if the healthcare leaders implement an effective preventive maintenance program for medical devices. The good point (GP) for this question is valid only if the user has answered the question with Very Good (Very Good: GP; Good: BP-PC-4; Medium: BP-PC-3; Poor: BP-PC-2; Very Poor: BP-PC-1).

In the next dimension, the user will be asked if the organisation's leaders implement policies and procedures to support the collection of information or not. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not implement policies and procedures to support the collection of information. This is also applicable to other KPIs that measure if the organisation's leaders provide staff with timely access to research, evidence and best practice information, and if its leaders regularly improve the organisation's information systems. The system has characterised the organisation as having a moderate problem with category PC-3, if its

leaders do not support and facilitate the flow of administrative information throughout the organisation.

### 4.6 Level 4: L6σ for QMHE

The last module that needs to be examined is *L6σ for QMHE*. This level helps to evaluate the on-going or completed L6σ projects conducted by the healthcare organisation. Therefore, this level assists in capturing data about the organisation's readiness before implementing L6σ and the degree of success in each phase (within the DMAIC cycle) after the implementation.

The user will be, in the beginning, asked some questions that will decide the ways of identifying services and the process of mapping value stream for a particular L6σ project in the healthcare organisation. Then, the system will evaluate L6σ implementation using the DMAIC process. The rules developed in the module will establish relationships, converting that data into information. *Level 4* can be illustrated in the model diagram shown in Figure 4.19.

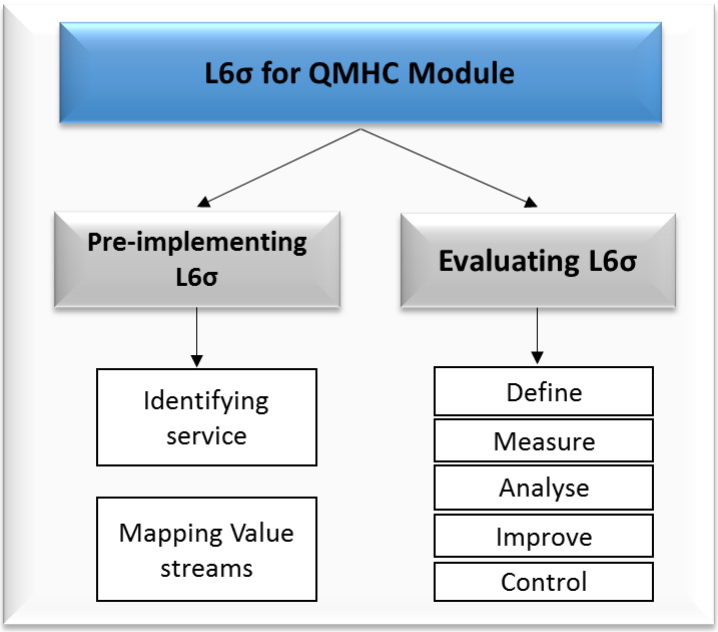


*Figure 4.19 IDEF0 Model for L6σ for QMHE*

By comparing the level of *L6σ for Quality Management in the Healthcare Environment* with the system benchmark, the module will convert that information into recommendations about which aspects need to be improved in a prioritised manner.

### *4.6.1 Pre-implementing L6σ*

The aim of this sub-module is to identify the organisation benchmark standard with respect to implementing L6σ. It aims also to evaluate the vision's clarity and level of recognition of L6σ, and team building strategy. Furthermore, it assesses the commitment from top level management, structured communication plan, and training strategy. Figure 4.20 illustrates that the assessment of *Pre-implementing L6σ* based on two dimensions; *identifying service and mapping value stream.*

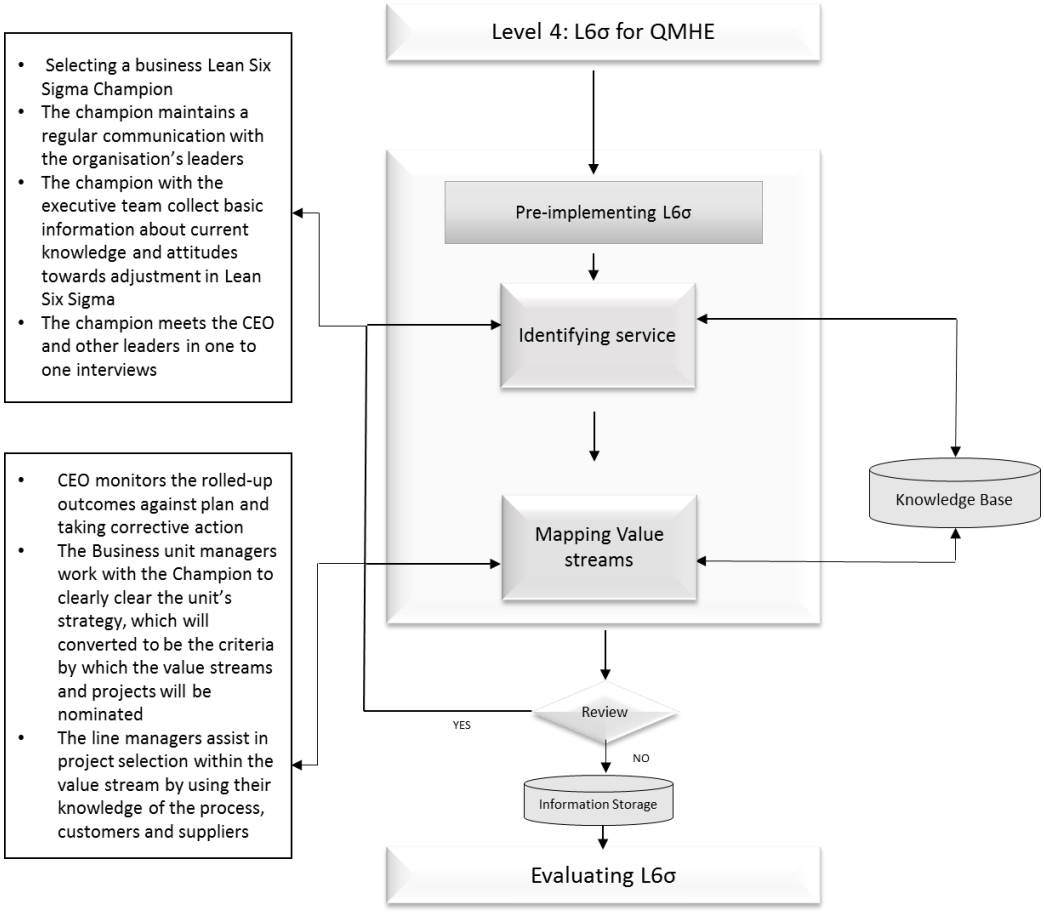


*Figure 4.10 Process flow chart of the pre-implementing L6σ sub-module*

The following example of KB set of rules is produced within the *pre-implementing L6σ* sub-module:

**IF** *the organisation's leaders select a business L6σ champion* ***(Yes: GP; No: BP-PC-1)***

**AND** *the champion with the executive team collects basic information about current knowledge towards adjustment in L6σ* ***(Yes: GP; No: BP-PC-2)***

**AND** *the champion involves key influencers through focus group interviews (****Yes: GP; No: BP-PC-3)***

**AND** *the champion provides an outline that shows some areas of the organisation that are more amenable to L6σ than others (****Yes: GP; No: BP-PC-3)***

**IF** *the organisation's leaders know why they are implementing strategies built on L6σ philosophies* ***(Yes: GP; No: BP-PC-2)***

**AND** *L6σ projects and results are always reflected on the organisation's meeting agenda and discussed in* ***(Yes: GP; No: BP-PC-3)***

**AND** *Black Belts and Champions receive 4 to 6 weeks of training (**Yes: GP; No: BP-PC-3)***

**AND** *the organisation's leaders undertake the accountability to supervise how the need and benefits of L6σ effort should be communicated to others **(Yes: GP; No: BP-PC-4)***

The above KB rules trigger the question that investigates whether the organisation's leaders select a business L6σ champion or not. The system has categorised the organisation as having a problem with category PC-1, if its leaders do not select a business L6σ champion. The system has categorised the organisation as having a problem with category PC-2, if the champion and the executive team, do not collect basic information about current knowledge towards adjustment in the L6σ. The system, also, has characterised the organisation as having a moderate problem with category PC-3, if L6σ champion does not involve key influencers through focus group interview and does not provide an outline that shows some areas of the organisation that are more amendments to L6σ than others.

In mapping value stream dimension, the user will be asked if the organisation's leaders know why they are implementing strategies built on L6σ philosophies or not. The system has categorised the organisation as having a problem with category PC-2, if its leaders do not know why they are implementing strategies built on L6σ philosophies. The system has characterised the organisation as having a moderate problem with category PC-3, if L6σ projects and results are not always discussed in the meeting agenda of the organisation. This is also applicable to other KPIs that measure if the BB and champions do not receive 4 to 6 weeks of training. The organisation is considered to have a minor problem category PC-4, if its leaders do not take into account to supervise how the need and benefits of L6σ effort should be communicated to others.

### *4.6.2 Evaluating L6σ*

The aim of this sub-module is to assess the implementation of L6σ in the healthcare organisation. This assessment is conducted by evaluating the whole DMAIC process. In fact, DMAIC is a data-driven approach that is structured in a way of learning from previous phases. However, only one methodology can be repeated again if this is not successful. Figure 4.21 illustrates the assessment of *evaluating L6σ* based on DMAIC process circle.

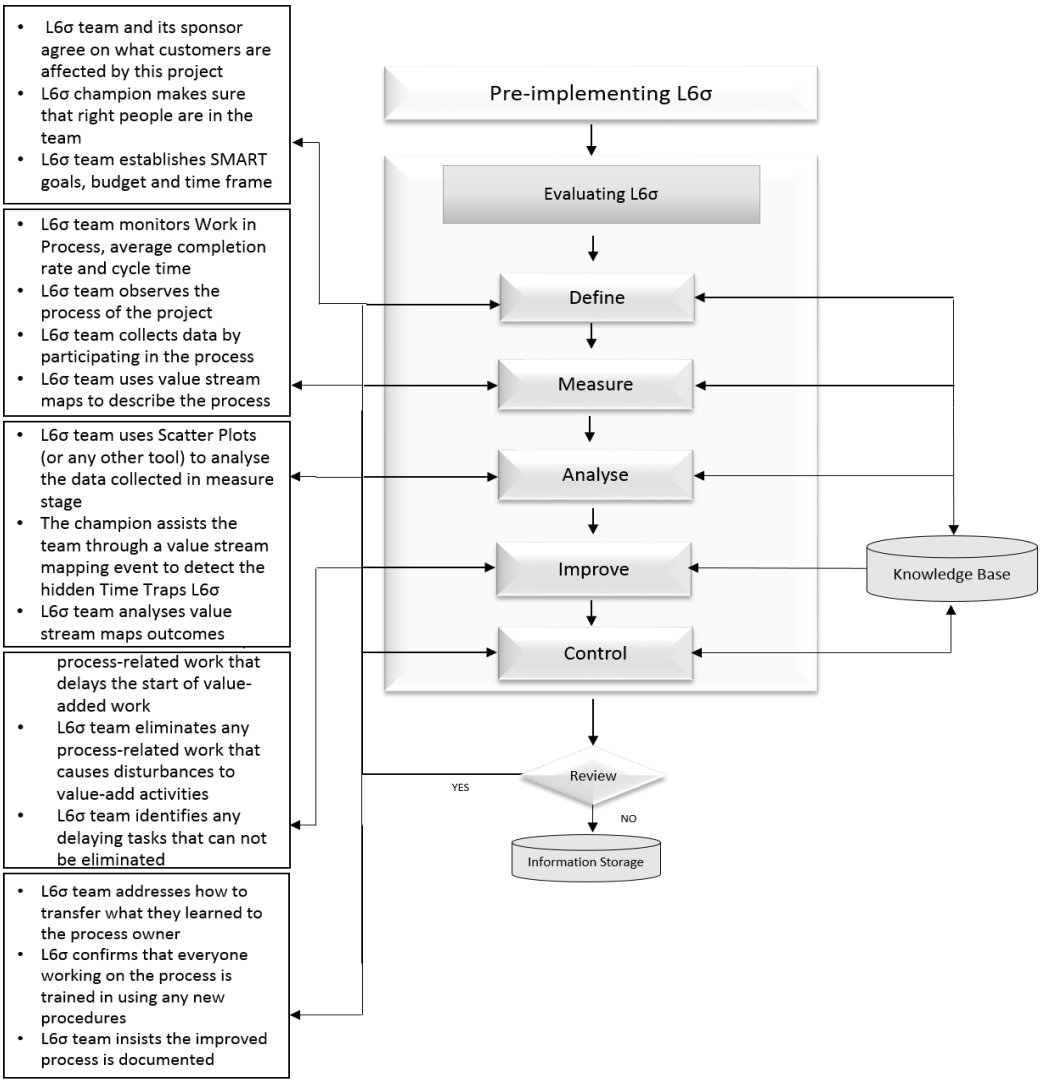


*Figure 4.11 Process flow chart of the evaluating L6σ sub-module*

The following example of KB set of rules is generated within the *evaluating L6σ* sub-module:

**IF** *L6σ team agrees on what customers are affected by this project* ***(Yes: GP; No: BP-PC-2)***

**AND** *L6σ team agrees on how the present process fails to meet customer needs* ***(Yes: GP; No: BP-PC-3)***

**IF** *as part of baseline metrics establishment, L6σ team monitors Work in Process (WIP)* ***(Yes: GP; No: BP-PC-2)***

**AND** *as part of baselines metrics establishment, L6σ team monitors defects capability* ***(Yes: GP; No: BP-PC-2)***

**IF** *L6σ team uses Scatter Plots (or any other tool) to analyse the data collected in measure stage* ***(Yes: GP; No: BP-PC-2)***

**AND** *L6σ team analyses value stream maps outcomes* ***(Yes: GP; No: BP-PC-2)***

**IF** *L6σ team eliminates any process-related work that delays the start of value-added work* ***(Yes: GP; No: BP-PC-2)***

**AND** *L6σ team puts the process under statistical control* ***(Yes: GP; No: BP-PC-3)***

**IF** *L6σ team addresses how to transfer what they learned to the process owner* ***(Yes: GP; No: BP-PC-2)***

**AND** *L6σ team develops a control plan* ***(Yes: GP; No: BP-PC-3)***

The above KB rules trigger the question that investigates whether the L6σ team agrees on what customers are affected by this project or not. The system has categorised the organisation as having a problem with category PC-2, if L6σ team does not agree on what customers are affected by this project. The system has categorised the organisation as having a problem with category PC-3, if L6σ team does not agree on how the present process fails to meet customers' needs.

In the measuring stage, the user will be asked if the L6σ team monitors Work in Process (WIP) as part of establishing baselines metrics. The system has categorised the organisation as having a problem with category PC-2, if it L6σ team monitors WIP as

part of establishing baselines metrics. This is also applicable if the L6σ team does not monitor defects capability.

Moving to the analysis stage, the user will be asked if L6σ team uses Scatter Plots (or any other tool) to analyse the data collected at the measure stage. The system has categorised the organisation as having a problem with category PC-2, if L6σ team does not use Scatter Plots (or any other tool) to analyse the data collected at the measure stage. This is also applicable if the L6σ team does not analyse value stream maps outcomes.

At the improving stage, the user will be asked L6σ team eliminates any process-related work that delays the start of value-added activities. The system has categorised the organisation as having a problem with category PC-2, if L6σ team does not eliminate any process-related work that delays the start of value-added activities. The system has categorised the organisation as having a problem with category PC-3, if L6σ team does not put the process under statistical control.

In the last stage of DMAIC, the user will be asked, as part of controlling stage, if L6σ team addresses how to transfer what they have learnt to the process owner. The system has categorised the organisation as having a problem with category PC-2, if L6σ team does not address how to transfer what they have learnt to the process owner. The system has categorised the organisation as having a problem with category PC-3, if L6σ team does not develop a control plan.

### 4.7 Summary

This chapter has discussed in detail the development of the KB L6σ-QMHE System. The system consists of strategic decision levels and operational decision levels. The strategic decision levels were divided into *Level 0: Healthcare Organisation's Environment, Level 1: Healthcare Governance* and *Level 2: Healthcare Leadership*.

At *Level 0: Healthcare Organisation's Environment* module, two sub-modules were discussed: *organisational statement* and *quality dimensions*. These contain general information about the organisation's statements and its quality dimensions. At *Level* 1, three sub-modules were presented: the *effective governing body* sub-module where the governing body's roles and responsibilities, its membership, and its process in decision making were highlighted, *supporting* sub-module where the governing body's supporting to chief executive, planning and patient safety were discussed, and the *sustainable results* sub-module which investigates the governing body in terms of its relations with community, promoting quality, and patient safety and evaluating performance.

At *Level 2,* the module discussed in detail the *Healthcare Leadership* module. It has further been categorised into four sub-modules: *creating a caring culture, planning and designing, planning for disasters and improving quality.* In *creating a caring culture* sub-module, KBS examined the healthcare leadership effectiveness in promoting and maintaining a caring culture. The *planning and designing* sub-module, measured the healthcare leadership efficiency in planning, designing and monitoring the community requirements. Moving to the *planning for disasters* sub-module, the system assessed the healthcare leaders in developing, implementing, and evaluating an all hazard, disaster, and emergency response. The last sub-module at the leadership level is *improving quality* where the healthcare leadership's ability to identify risk and enhance the patient safety were assessed.

The operational decision levels follow within the development of the KB L6σ-QMHE System. At *Level 3: Healthcare Organisation's Resources* module, the system integrated three sub-modules. The *human resources* sub-module evaluated the healthcare leadership's ability to develop and implement recruiting and retention strategies for the staff in the organisation. It was followed by assessing the *physical capital* sub-module

with respect to the effectiveness of financial resources allocation decisions and budget monitoring in the organisation. Finally, the *technical resources* sub-module was assessed by measuring the healthcare leadership's ability to select and buy medical devices and equipment. It was also assessed, by evaluating the process of selecting and implementing of information management systems in the organisation.

The last level of the operational decision process is *Level 4: L6σ for Quality Management at Healthcare*. Two sub-modules were assessed in this module: *pre-implementing L6σ and evaluating L6σ.* In the *pre-implementing L6σ* sub-module, the KBS measured the organisational benchmark standard with respect to implementing L6σ and evaluated the clarity of the vision and level of recognition of L6σ, as well as the team building strategy. Furthermore, *evaluating L6σ* sub-module examined the efficient use of the DMAIC cycle by testing the fulfilment of implementing each phase (i.e. Define, Measure, Analyse, Improve, and Control).

Each of the above mentioned levels helped to capture the required data. The rules embedded in each module were used to establish relationships, converting data into information. By assessing and comparing the level of performance of the organisation, each module was used to convert information into recommendations about strategic or operational issues of the organisation (knowledge or know-how).

In general, Chapter 4 discussed in detail the development process of the KB L6σ-QMHE system, which consists of Levels 0, 1, 2, 3, and 4. In Chapter 5, the discussion will be carried out in validating the KB L6σ-QMHE system via real healthcare implementation.

# Chapter 5: Validation of KB L6σ-QMHE System

## 5.1 Introduction

This chapter covers the fifth and the sixth objectives of the research by presenting a detailed validation process of the KB L6σ-QMHE system. In order to perform these processes, the KB L6σ-QMHE system is populated with data from an actual healthcare environment. The aim is to ensure the integrity of acquiring and translating the know-how of experts in a healthcare environment and academia into an explicit form within the system. In addition, the validation of the system also considers the capability of identifying and recommending the areas that need improvements in a priority order. According to Batarseh and Gonzalez (2015), the validation requires subject experts' involvement to have effective knowledge representation and confident assessment of the system. This research will follow a similar approach to the validating technique conducted by Aldairi et al. (2017)

Hence, this chapter is concentrated on the validation and refinement of the KB L6σ-QMHE system. The validation process has been conducted in the three largest hospitals in Oman based on the KB L6σ-QMHE system requirements from 13$^{th}$ December 2017 to 10$^{th}$ January 2018 as Appendix E shows. The validation process involved the healthcare quality management experts applying the KB L6σ-QMHE system in their hospitals' quality management systems. Sultan Qaboos University (SQUH) and Royal Hospital (RH) were validated in full based on the five levels of the system, while Khoula Hospital (KH) was validated based on the first four levels, this is because it did not implement the L6σ philosophies in its environment.

### 5.2 Healthcare environment Validation Process

As mentioned, the validation process was carried out in the three largest healthcare organisations in Oman. The three hospitals were selected because they are considered to be the largest hospitals in Oman. Moreover, the validation process aimed to compare between the hospitals which applied L6σ principles; (SQUH and RH) with KH which does not apply L6σ philosophies. Additionally, RH and KH considered to be a MoH hospitals whereas SQUH is an independent hospital.

As part of the validation process, the researcher has uploaded the KB rules and transformed them to questions for easy response. He has arranged a meeting with five healthcare QM expert in the targeted hospitals (2 from SQUH, 2 from RH and 1 from KH). During the meeting, the experts were encouraged to use the system and to write down any comments, gaps or opportunity for improvement. Each expert was requested to answer the questions based on the current practise in his/her hospital.

In fact, SQUH launched the L6σ training in 2015; this was carried out through teaching members of staff from different disciplines. Different L6σ projects were also conducted from that time to improve the services in the hospital. The director of development and quality as well as the head of quality monitoring participated in the validation process in SQUH. Recently, the RH started a performance improvement department under the umbrella of QM system in the hospital which takes responsibilities of L6σ projects. In RH, the head of quality and patient safety, and the head of performance improvement have been involved in the validation process. In KH, where the system was validated partially *(Level 0 to Level 3),* the head of quality and patient safety was involved in the validation process. This was followed by comparing the recommendations with their own expert views and opinions. The following briefs describe the healthcare organisations that participated in this validation process.

### *5.2.1 Sultan Qaboos University Hospital (SQUH)*

SQUH was opened by His Majesty Sultan Qaboos Bin Said in 1990. '*It is an educational as well as medical institution, performing five main functions of teaching medical students, providing undergraduate and postgraduate medical training, promoting research and offering tertiary medical care'* (Squh, 2016). The journey of quality in SQUH started in 2003, when the hospital administration signed a contract with a quality assurance firm to train multi-functional teams about quality principles and concepts. These efforts yielded results, the hospital was awarded its first international standards certification award, ISO 9001:2000 in 2005 and re-certified twice in 2008 and 2011. The journey did not stop with the ISO accreditation, but went further, with the hospital also accredited by ACI in 2014 and re-certified in 2017.

### *5.2.2 Royal hospital (RH)*

This Royal Hospital is owned and administered by the MoH, the Sultanate of Oman commissioned this facility in 1987. The hospital has a capacity to provide services to 630 in-patients admitted through the divisions of child health, medicine, surgery, obstetrics and gynaecology, and oncology. The hospital places much emphasis on the delivery of quality healthcare. The Medical Committee meets once a month to review risk management statistics, performance indicators, and quality improvement initiatives. There is also a clinical audit committee to audit quality of care and monitor mortality and morbidity audits conducted by various divisions and departments in the hospital. Other activities undertaken by the quality management system office include: monitoring of adverse events, accidental inoculation injuries, quality improvement teams, and patient

satisfaction surveys (Oman-MoH, 2018b). This hospital was accredited by the ACI in 2017.

### *5.2.3 Khoula Hospital (KH)*

Khoula hospital came in to existence in the year 1974. It is a teaching hospital recognised by the Royal College of Surgeons, UK for general surgery, orthopaedics, plastic surgery and neuro surgery. It is a secondary care hospital in the Region of Muscat (Capital of Oman), it provides tertiary services for the country, in areas such as orthopaedics, neuro surgery, plastic surgery and burns. This is a 517 bed hospital, and hosts the National trauma centre; it has a staff strength of 1781 employees. It also serves as a teaching hospital for medical students of Sultan Qaboos University, Oman Medical College, Oman Specialty Board Doctors, and other paramedical and nursing students (Oman-MoH, 2018a).

## 5.3 Validation of KB L6σ-QMHE

The KB L6σ-QMHE system consists of five decision-making Levels starting from *Level 0: Healthcare Organisation's Environment* and ending at *Level 4: L6σ implementation.* These levels have been designed as shown in the reprinted conceptual framework of Figure 3.6. For *Level 0 to Level 3*, the process of validation was carried out with KH. In fact, they were not able to participate in the validation of *Level 4* as they do not implement any L6σ project currently.

The same validation process was carried out for *Level 4* in SQUH and RH, as they have previously conducted different *L6σ* projects. The detailed inputs, outputs, and analysis of SQUH are used in this chapter to show the KB L6σ-QMHE capability during the process of validating the modules. The KH and RH analysis results are presented at

the end of the chapter as a summary, while the detailed inputs and outputs are shown in Appendix F and G. Therefore, Sections 5.3 to 5.4 are the KB L6σ-QMHE results and discussion of SQUH. Section 5.5 presents the results' summary and discussion of RH. The final Section 5.6 presents the results and discussion of KH.

### *5.3.1 Organisation SQUH: Level 0 – Healthcare Organisation's Environment*

This section will show how the *Healthcare Organisation's Environment* Level will help in capturing data about the statement of SQUH and its quality dimensions. It will also show how the rules implanted in the module will establish relationships, converting that data into information. By assessing or comparing the level of performance of SQUH, the module will convert these information into recommendations about strategic issues of the hospital (knowledge or know-how). The *Level 0: Healthcare Organisation's Environment* of the L6σ-QMHE system consists of two sub-modules: *healthcare organisational statement* and *healthcare quality dimensions* as shown in Figure 5.1 and illustrated in Chapter 4.

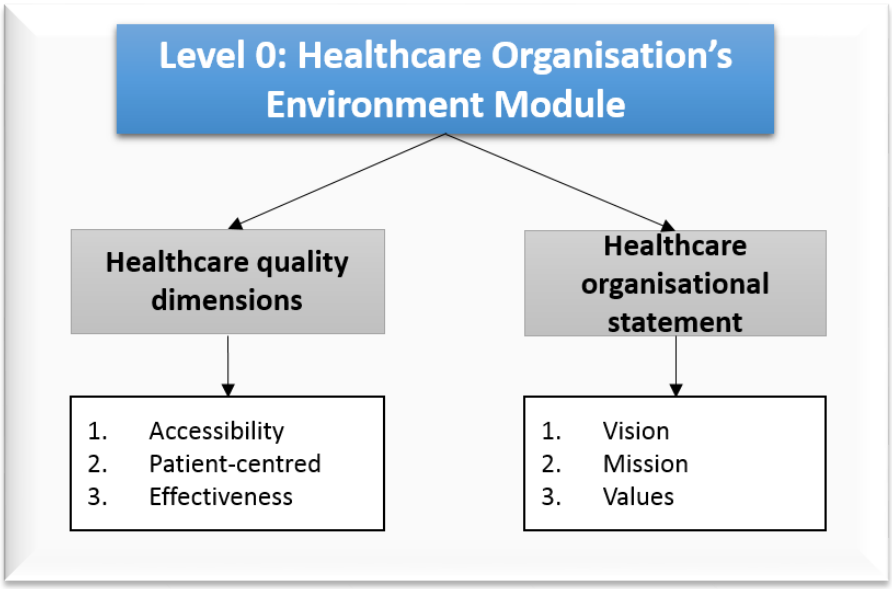


*Figure 5.1 Level 0, Module of Healthcare Organisation's Environment*

Based on the answers provided by users in SQUH, the GAP analysis results of *Level 0: Healthcare Organisation's Environment* were summarised and tabulated, as seen in Table 5.1. These results reflect the difference between the existing practice and the benchmarked practice. There are a total of 115 KB rules triggered in this module which include the number of GPs, and the number of BPs rated as problem categories (PCs) from PC-1 to PC-5. The optimisation technique (GAP analysis) in this research suggests that only the BPs are categorised as PC in order to find out the necessary pre-requisites for further improvements. Out of 115 KB rules triggered, the system has categorised 44 as GPs, and the remaining 71 as BPs. The 71 BPs are classified into different PCs (13 PC-1, 19 PC-2, 17 PC-3, 22 PC-4, and 0 PC-5) where they represent the activities that need to be improved to achieve a full KBL6σ-QMHE implementation.

*Table 5.1 GAP analysis results of SQUH Level 0: Healthcare Organisation's Environment*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Healthcare organisational statement** | Vision | **19** | **6** | **13** | **8** | **3** | **2** | **0** | **0** |
| | Mission | **19** | **9** | **10** | **5** | **0** | **5** | **0** | **0** |
| | Values | **14** | **11** | **3** | **0** | **2** | **1** | **0** | **0** |
| | **Sub-total** | **52** | **26** | **26** | **13** | **5** | **8** | **0** | **0** |
| **Healthcare quality dimensions** | Accessibility | **9** | **1** | **8** | **0** | **2** | **1** | **5** | **0** |
| | Patient-centred | **30** | **7** | **23** | **0** | **6** | **6** | **11** | **0** |
| | Effectiveness | **24** | **10** | **14** | **0** | **6** | **2** | **6** | **0** |
| | **Sub-total** | **63** | **18** | **45** | **0** | **14** | **9** | **22** | **0** |
| **Total** | | **115** | **44** | **71** | **13** | **19** | **17** | **22** | **0** |

In the *healthcare organisational statement* sub-module, a total of 52 KB rules were triggered of which 26 were GPs (meaning that the requisites for these were met). However, there were 26 KB rules, which were not met (BPs), indicating a gap in the requisites for achieving benchmark. A further analysis of these BPs show that major key BPs were in the dimensions of *Vision*, and *Mission*.

A key aspect from this analysis reveals that in the *Vision* dimension there were13 BPs, of which 8 are in PC-1 and 3 in PC-2. This shows an extremely important factor that can negatively affect the organisation from achieving its vision. It was further revealed from the user's answers that SQUH's governing body, in consultation with the chief executive, is not monitoring responsibilities for achieving the strategic goals or identifying timeframes for achieving objectives. Thus, SQUH has to focus on rectifying the problems from category 8 PC-1 before fixing the other 5 PCs (3 PC-2, and 2 PC-3).

In the *healthcare quality dimensions* sub-module, a total of 63 KB rules were triggered of which 18 were GPs. However, there were 45 KB rules, which were not met (BPs), indicating a gap in requisites for achieving the benchmark. Further analysis of these BPs show that key BPs were in the dimensions of *patient-centred*, and *effectiveness*. A critical aspect from this analysis is that in the *patient-centred* dimension there were 23

BPs (of which 6 were in PC-2 and 6 in PC-3). The KB rules indicate that some of the patients' feedbacks about their views were not taken in consideration. They feel that the healthcare providers do not involve them in the decision-making process, as well as consider their preferences. The impact of not paying attention to the involvement of patients and their families in the decision-making process definitely cascades to other dimensions in the KB L6σ-QMHE system.

The above GAP analysis has been used by the KB L6σ-QMHE system to produce the AHP analysis. As discussed in Section 3.5.4, AHP is used to determine which aspects should be prioritised for further improvements. The integrated AHP will start the analysis by determining the values of Priority Vectors (PVs) in each sub-module. *Super decision* Software has been used to calculate the PVs in this system. For the sub-modules, *healthcare organisational statement* and *healthcare quality dimensions*, the PV values of each dimension have been calculated as represented in Tables 5.2, and 5.3 respectively.

*Table 5.2 Healthcare organisational statement AHP analysis with PV for SQUH*

| **Healthcare organisational statement** | Vision | Mission | Values | P.V |
|---|---|---|---|---|
| Vision | 1 | 2 | 2 | **0.50** |
| Mission | 1/2 | 1 | 1 | 0.25 |
| Values | 1/2 | 1 | 1 | 0.25 |

In fact, the process of pairwise comparisons was done based on the KB outputs after using the GAP analysis method in each module. For example, mission is twice important than vision as Table 5.2 shows. The next step is to synthesis the judgments by adding-up the value in each column to get the total value. For example, 1+0.5+0.5= 2 in Table 5.2. Thereafter, divide each entry in a column by the total value of that specific column. For example, 1/2= 0.5, 0.5/2= 0.25 and 0.5/2= 0.25. Finally, PV can be identified by calculating average value of vision, mission and values in each row.

Table 5.2 shows the PV values in the *healthcare organisational statement* sub-module. The values are **0.500** for *vision,* 0.250 for *mission* and 0.250 for *values*. This means that focusing on this sub-module, SQUH's priority is to rectify the dimension of *vision* before attempting the dimensions of *mission* and *values.*

*Table 5.3 Healthcare quality dimensions AHP analysis with PV for SQUH*

| **Healthcare quality dimensions** | Accessibility | Patient-centred | Effectiveness | P.V |
|---|---|---|---|---|
| Accessibility | 1 | 3/2 | 3/2 | 0.245 |
| Patient-centred | 2/3 | 1 | 2 | **0.463** |
| Effectiveness | 2/3 | 1/2 | 1 | 0.292 |

Table 5.3 indicates the PV values for the *healthcare quality dimensions* sub-module. The PV values for *accessibility*, *patient-centred*, *and effectiveness* are 0.245**,** **0.463,** and 0.292 correspondingly. Therefore, the priority for SQUH is to focus on this sub-module in order to improve on the dimension *patient-centred* (this was highlighted due to the lack of patients' ability to express their views and receive feedback about their views) before attempting the dimensions *accessibility* and *effectiveness.*

The next phase of the analysis uses the same AHP process to determine the PV values at the sub-modules' stage of *healthcare organisational statement*, and *healthcare quality dimensions*. The summary of these sub-modules PV values is tabulated in Table 5.4. The values are 0.333 for *healthcare organisational statement* and **0.667** for *healthcare quality dimensions*. This means that by focusing on this module, SQUH's priority is to rectify the sub-module of *healthcare quality dimensions statement,* followed by the *healthcare organisational statement* sub-module.

*Table 5.4 Healthcare Organisation's Environment AHP analysis with PV for SQUH*

| **Level 0** | Healthcare organisational statement | Healthcare quality dimensions | P.V |
|---|---|---|---|
| Healthcare organisational statement | 1 | 1/2 | 0.333 |
| Healthcare quality dimensions | 2 | 1 | **0.667** |

Table 5.5 summarises the AHP-PV values for each of the dimensions and sub-modules for the *Healthcare Organisation's Environment* module. The KB L6σ-QMHE analysis proposes that SQUH should first centre their efforts on resolving the area of *healthcare quality dimensions* due to the highest PV of **0.667**. The KB L6σ-QMHE also recommends SQUH to improve the *patient-centred* dimension which has a PV of **0.463**.

The KB L6σ-QMHE analysis also recommends that SQUH should focus on the *healthcare organisational statement* sub-module (PV = 0.333). The analysis further reveals SQUH should give more attention to the *vision* dimension that has a PV of 0.500 before dealing with the other two dimensions.

*Table 5.5 Summary of AHP PV values for Level 0: Healthcare Organisation's Environment for SQUH*

| **Sub-module** | **Priority Vector** | **Dimensions** | **Priority Vector** |
|---|---|---|---|
| **Healthcare organisational statement** | 0.333 | Vision | **0.50** |
| | | Mission | 0.25 |
| | | Values | 0.25 |
| **Healthcare quality dimensions** | **0.667** | Accessibility | 0.245 |
| | | Patient-centred | **0.463** |
| | | Effectiveness | 0.292 |

In summary, for Level 0, the KB L6σ-QMHE system analysis has recorded the GAP analysis of 71 BPs from 115 KB rules triggered. This reveals that SQUH is 61.73% (71 BPs out of 115) below the benchmark standard in their *Healthcare Organisation's*

*Environment*. The KB L6σ-QMHE analysis concluded that SQUH needs to take action to improve the *patient-centred* dimension in the *healthcare quality dimensions* sub-module.

### *5.3.2 Organisation SQUH: Level 1 – Healthcare Governance*

This section will show how the *Healthcare Governance* Level helps in capturing data about the SQUH's governing body, its support systems, and assess its sustainable results. It will also show how the rules implanted in the module will establish relationships, converting these data into information. By assessing or comparing the level of performance of SQUH, the module will convert these information into recommendations about strategic issues of the hospital (knowledge or know-how). The *Level 1: Healthcare Governance* of the L6σ-QMHE system will consist of three sub-modules: *effective governing body*, *supporting* and *sustainable results* as shown in Figure 5.2 and illustrated in Chapter 4.

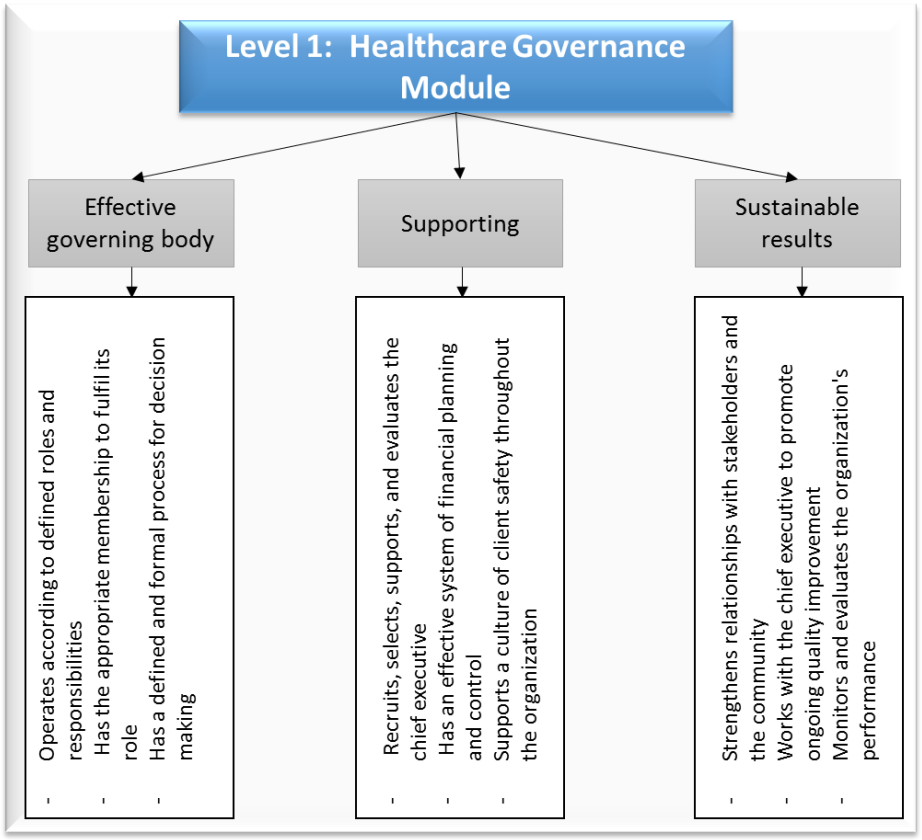


*Figure 5.2 Level 1, Module of Healthcare Governance*

Based on the responses from users in SQUH, the GAP analysis results of *Level 1: Healthcare Governance module* have been summarised and arranged, as seen in Table 5.6. These results reflect the difference between the existing practice and the benchmarked practice. There have been a total of 212 KB rules triggered in this module which include the number of GPs, and the number of BPs rated as problem categories (PCs) from PC-1 to PC-5. As mentioned in Level 0, the optimisation technique (GAP analysis) in this research suggests that only the BPs are categorised as PC in order to find out the requisites for further improvements. Out of 212 KB rules generated, the system has categorised 152 as GPs and the remaining 60 as BPs. The 60 BPs are classified into different problem categories (26 PC-1, 26 PC-2, 8 PC-3, 0 PC-4, and 0 PC-5) where they represent the activities that need to be improved to achieve a full KB L6σ-QMHE implementation.

*Table 5.6 GAP analysis results of SQUH Governance*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Effective governing body** | Roles and responsibilities | **29** | **21** | **8** | **8** | **0** | **0** | **0** | **0** |
| | Membership | **53** | **49** | **4** | **0** | **4** | **0** | **0** | **0** |
| | Decision-making | **11** | **11** | **0** | **0** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **93** | **81** | **12** | **8** | **4** | **0** | **0** | **0** |
| **Supporting** | Evaluating the CEO | **15** | **15** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Financial planning | **28** | **28** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Supporting patient safety culture | **11** | **1** | **10** | **10** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **54** | **44** | **10** | **10** | **0** | **0** | **0** | **0** |
| **Sustainable results** | Relations with community | **21** | **17** | **4** | **0** | **0** | **4** | **0** | **0** |
| | Promoting quality improvement | **18** | **1** | **17** | **0** | **17** | **0** | **0** | **0** |
| | Monitoring performance | **26** | **9** | **17** | **8** | **5** | **4** | **0** | **0** |
| | **Sub-total** | **65** | **27** | **38** | **8** | **22** | **8** | **0** | **0** |
| **Total** | | **212** | **152** | **60** | **26** | **26** | **8** | **0** | **0** |

In the *effective governing body* sub-module, a total of 93 KB rules were triggered of which 81 were GPs (meaning that the requisites for these were met). However, there were 12 KB rules, which were not met (BPs), indicating a gap in the requisites for achieving this benchmark. A further analysis of these BPs show that major key BPs were in the dimensions of *roles and responsibilities,* and *membership*. A key aspect from this analysis reveals that in the *roles and responsibilities* dimension 8 BPs were identified of which all of them are in PC-1. This also reveals an extremely important factor that can affect the operation of the health care facility according to defined roles and responsibilities, as well as meeting its legal obligations in this regard. It was further revealed that SQUH's governing body does not have a developed process that appoints and elects its chair. Thus, SQUH has to focus on rectifying the problems from category 8 PC-1.

In the *supporting* sub-module, a total of 54 KB rules were triggered of which 44 were GPs. However, there were 10 KB rules, which were not met (BPs), indicating a gap in the requisites for achieving this benchmark. Further analysis of these BPs shows that all BPs were in the dimension of *supporting patient safety culture*. A critical aspect from this analysis is that in this dimension there were 10 BPs (of which were in 10 PC-1). This is also a significant factor that can negatively affect supporting patient safety culture. It was further revealed that the hospital's governing body does not regularly use the information of adverse events and near misses to understand client safety issues in the organisation. Thus, the hospital has to focus on correcting these problems of 8 PC-1 urgently.

Lastly, for the *sustainable results* sub-module, out of 65 KB rules produced, there were 27 GPs and 38 BPs. Further analysis of these BPs shows that key BPs were in the dimensions of *promoting quality improvement* and *monitoring performance*. This further show that the hospital's governing body does not promote learning from making decisions that are informed by research and evidence for the organisation. Similarly, the hospital does not monitor data to assess its performance as well as identify opportunities for improvement in relation to how it functions. Furthermore, SQUH's governing body does not work with the chief executive to develop an integrated quality improvement plan and does not have strategies to address client flow in service demands.

As mentioned in *Level 0*, the above GAP analysis has been used by the KB L6σ-QMHE system to produce the AHP analysis. This step is very important as it determines which aspects should be prioritised for further improvements. The integrated AHP will starts the analysis by determining the values of PVs in each sub-module. For the sub-modules *effective governing body, supporting, and sustainable results*, the PV values of

each dimension have been calculated as represented in Tables 5.7, 5.8, and 5.9 respectively.

*Table 5.7 Effective governing body AHP analysis with PV for SQUH*

| **Effective Governing Body** | Roles and responsibilities | Membership | Decision making | P.V |
|---|---|---|---|---|
| Roles and responsibilities | 1 | 2 | 4 | **0.571** |
| Membership | 1/2 | 1 | 2 | 0.286 |
| Decision making | 1/4 | 1/2 | 1 | 0.143 |

Table 5.7 shows the PV values in the *effective governing body* sub-module. The values are **0.571** for *roles and responsibilities*, 0.286 for *membership* and 0.143 for *decision making*. This means that focusing on this sub-module, SQUH's priority is to rectify the dimension of *roles and responsibilities* before attempting the other two dimensions.

*Table 5.8 Supporting AHP analysis with PV for SQUH*

| **Supporting** | Evaluating the CEO | Financial planning | Supporting patient safety culture | P.V |
|---|---|---|---|---|
| Evaluating the CEO | 1 | 1 | 1/3 | 0.2 |
| Financial planning | 1 | 1 | 1/3 | 0.2 |
| Supporting patient safety culture | 3 | 3 | 1 | **0.6** |

Table 5.8 indicates the PV values for the *supporting* sub-module. The PV values for *evaluating the CEO, financial planning,* and *supporting patient safety culture* are 0.2, 0.2, and **0.6** respectively. Therefore, the priority for SQUH is to focus on this sub-module in order to improve the dimension *supporting patient safety culture* (this was highlighted because the governing body does not monitor organisation-level measures of client safety

and does not addresses recommendations made in the organisation's quarterly client safety reports) before attempting *evaluating the CEO* and *financial planning.*

*Table 5.9 Sustainable results AHP analysis with PV for SQUH*

| **Sustainable Results** | Relations with community | Promoting quality improvement | Monitoring performance | P.V |
|---|---|---|---|---|
| Relations with community | 1 | 1/4 | 1/3 | 0.124 |
| Promoting quality improvement | 4 | 1 | 3/2 | **0.517** |
| Monitoring performance | 3 | 2/3 | 1 | 0.359 |

Table 5.9 shows the PV values for the *sustainable results* sub-module. The PV values for *relations with community*, *promoting quality improvement*, and *monitoring performance* are 0.124, **0.517**, and 0.359 respectively. Therefore, the priority for SQUH is to focus on this sub-module in order to improve the dimension *promoting quality improvement* (this was highlighted because the governing body does not monitor input into the organisation's strategies so as to address client flow in service demands) before attempting the other two dimensions.

The next analysis uses the same AHP process to determine the PV values at the sub-modules' stage of *effective governing body*, *supporting*, and *sustainable results*. The summary of these sub-modules PV values is tabulated in Table 5.10. The values are 0.297 for *effective governing body*, 0.163 for *supporting*, and **0.540** for *sustainable results*. This means that by focusing on this module, SQUH's priority will be to rectify the sub-module of *sustainable results,* followed by the *effective governing body* sub-module, and finally the *supporting* sub-module.

*Table 5.10 Level 1: Healthcare Governance AHP analysis with PV for SQUH*

| **Level 1** | Effective governing Body | Supporting | Sustainable results | P.V |
|---|---|---|---|---|
| Effective governing Body | 1 | 2 | 1/2 | 0.297 |
| Supporting | 1/2 | 1 | 1/3 | 0.163 |
| Sustainable results | 2 | 3 | 1 | **0.540** |

Table 5.11 summarises the AHP-PV values for each of the dimensions and sub-modules for the *Healthcare Governance* module. The KB L6σ-QMHE analysis proposes that SQUH first core efforts should be in resolving the area of *sustainable results;* this is because of the high PV of **0.540**. The system, also, recommends SQUH to improve on the *promotion of quality improvement* dimension which has a PV of **0.517**.

The KB L6σ-QMHE analysis recommends that SQUH should then focus on the *effective governing body* sub-module (PV = 0.33) before proceeding to improve. In relation to this sub-module, more attention has to be given to the *roles and responsibilities* dimension that has a PV of **0.571**, whereas in the *supporting* sub-module, SQUH needs to concentrate on the *supporting patient safety culture* (PV = **0.6**).

*Table 5.11 Summary of AHP PV values for Level 1: Healthcare Governance for SQUH*

| **Sub-module** | **Priority Vector** | **Dimensions** | **Priority Vector** |
|---|---|---|---|
| **Effective governing body** | 0.297 | Roles and responsibilities | **0.571** |
| | | Membership | 0.286 |
| | | Decision making | 0.143 |
| **Supporting** | 0.163 | Evaluating the CEO | 0.2 |
| | | Financial planning | 0.2 |
| | | Supporting patient safety culture | **0.6** |
| **Sustainable results** | **0.540** | Relations with community | 0.124 |
| | | Promoting quality improvement | **0.517** |
| | | Monitoring performance | 0.359 |

In summary, for *Level 1*, the KB L6σ-QMHE system analysis has recorded the GAP analysis of 60 BPs from 212 KB rules triggered. This reveals that SQUH's

governing body is 28.30% below the benchmark to fulfil the requirements of full L6σ-QMHE implementation. The KB L6σ-QMHE analysis concludes that SQUH needs to take action to improve the *promotion of quality improvement* dimension in the *sustainable results* sub-module.

### *5.3.3 Organisation SQUH: Level 2 – Healthcare Leadership*

This section will illustrate how the *Healthcare Leadership* Level will help in capturing data about SQUH's creating care culture, its leadership's ability in planning and designing and how it maintains a quality improvement. By assessing or comparing the level of performance of SQUH's leadership, the module will translate these information into recommendations about strategic issues of the hospital (knowledge or know-how). The *Level 2: Healthcare Leadership* of the L6σ-QMHE system contains four sub-modules: *creating a caring culture, planning and designing, planning for disaster,* and *improving quality* as shown in Figure 5.3 and illustrated in Chapter 4.

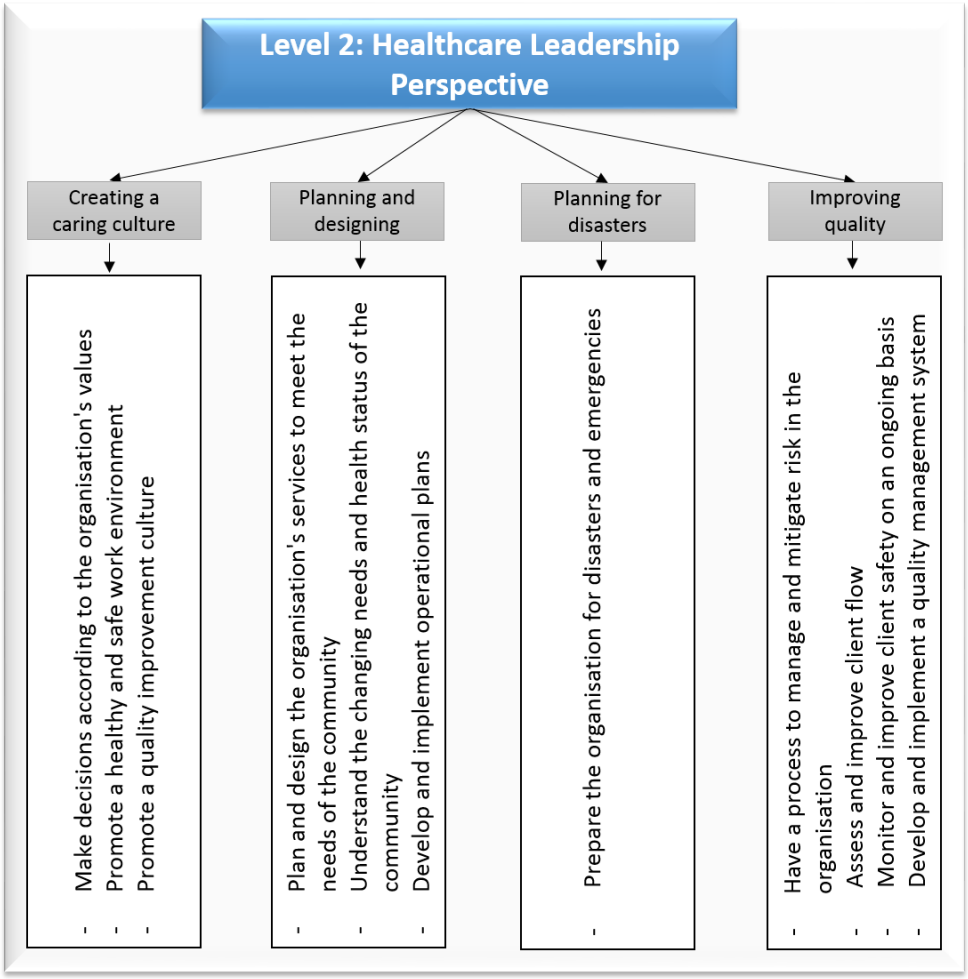


*Figure 5.3 Level 2: Module of Healthcare Leadership*

Based on the answers from the users in SQUH, the GAP analysis results of *Level 2: Healthcare Leadership module* was summarised and arranged as seen in Table 5.12. These results show the difference between the existing practice and the benchmarked practice. There have been a total of 384 KB rules produced in this module which include the number of GPs, and the number of BPs rated as problem categories (PCs) from PC-1 to PC-5. The optimisation technique (GAP analysis) in this research suggests that only the BPs are categorised as PC in order to find out the requisites for further improvements. Out of 384 KB rules triggered, the system has categorised 304 as GPs and the remaining 80 as BPs. The 80 BPs are classified into different PCs (0 PC-1, 22 PC-2, 36 PC-3, 22 PC-4, and 0 PC-5). Although, KB L6σ-QMHE has proven that SQUH does not have any

BPs in PC-1, but it needs to fill the gaps in other PCs to fulfil the requirements of full L6σ-QMHE implementation.

*Table 5.12 GAP analysis results of SQUH Leadership*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Creating a caring culture** | Decisions according values | **28** | **28** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Promoting a safe work environment | **40** | **40** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Promoting a quality culture | **44** | **2** | **42** | **0** | **9** | **17** | **16** | **0** |
| | **Sub-total** | **112** | **70** | **42** | **0** | **9** | **17** | **16** | **0** |
| **Planning and designing** | Planning for community needs | **80** | **72** | **8** | **0** | **0** | **8** | **0** | **0** |
| | Understanding community health status change | **34** | **17** | **17** | **0** | **8** | **8** | **1** | **0** |
| | Developing an operational plans | **46** | **44** | **2** | **0** | **0** | **0** | **2** | **0** |
| | **Sub-total** | **160** | **133** | **27** | **0** | **8** | **16** | **3** | **0** |
| **Planning for disasters** | Preparing for disasters and emergencies | **44** | **44** | **0** | **0** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **44** | **44** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Improving quality** | Managing risk | **20** | **20** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Improving client flow | **14** | **12** | **2** | **0** | **2** | **0** | **0** | **0** |
| | Improving client safety | **21** | **21** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Implementing a QM system | **13** | **4** | **9** | **0** | **3** | **3** | **3** | **0** |
| | **Sub-total** | **68** | **57** | **11** | **0** | **5** | **3** | **3** | **0** |
| **Total** | | **384** | **304** | **80** | **0** | **22** | **36** | **22** | **0** |

In the *creating a caring culture* sub-module, a total of 112 KB rules were triggered of which 70 were GPs (meaning that the requisites for these were met). However, there were 42 KB rules, which were not met (BPs), indicating a gap in requisites for achieving benchmark. A further analysis of these BPs shows that all key BPs were in the dimension of *promoting a quality culture*. A key aspect from this analysis shows that there were a total of 42 BPs (of which 9 PC-2, 17 PC-3 and 16 PC-4) in this dimension. These results reveal a significant factor that can negatively affect the promotion of a quality culture in

the healthcare environment. The analysis further shows that, the hospital's leaders do not promote the development of a confidential process for staff to bring forward concerns and complaints. Similarly, the hospital has to focus on correcting the problems from category 9 PC-2 before fixing the other 17 PC-3 and 16 PC-4.

In the *planning and designing* sub-module, a total of 160 KB rules were triggered of which 133 were GPs. However, there were 27 KB rules, which were not met (BPs), indicating a gap in the requisites for achieving this benchmark. An advance analysis of these BPs shows that key BPs were in the dimensions of *understanding community health status change* and *planning for community needs.* A critical aspect from this analysis is in the *understanding community health status change* dimension, and there were 17 BPs (of which 8 were in PC-2, 8 in PC-3, and 1 in PC-4). This shows a significant factor that can negatively affect community health status. The analysis further highlights that the hospital's information about the community is not maintained in a format that is easy to understand and the leaders do not share the information about the community with clients and families.

Similarly, for the *planning of the disaster* sub-module, out of 44 KB rules triggered, all of them were GBs. These results reflect the role of SQUH's leaders in developing and implementing plans for mitigating disasters and emergencies. Although, KB L6σ-QMHE has proven that SQUH is not practising any BPs in this sub-module, but it needs to fill other module gaps in order to fulfil the requirements of full L6σ-QMHE implementation.

Finally, for the *improving quality* sub-module, out of 68 KB rules generated, there were 57 GPs and 11 BPs. A more analysis of these BPs show that major key BPs were in the dimension of *implementing a quality management system*. A key aspect from this analysis is that in this dimension 9 BPs (3 were in PC-2, 3 in PC-3 and 3 in PC-4). The

analysis reveals a significant factor that can negatively affect the implementation of quality management. The analysis further shows that the leaders in the hospital do not monitor service, unit, or program areas, and outcome measures in order to align with the broader organisational strategic goals and objectives.

Again, the above GAP analysis has been used by the KB L6σ-QMHE system to produce the AHP analysis. This step is very important as it determines which aspects should be prioritised for further improvements. The integrated AHP will start the analysis by determining the values of PVs in each sub-module. For the sub-modules *creating a caring culture, planning and designing, planning for disaster* and *improving quality*, the PV values of each dimension have been calculated as represented in Tables 5.13, 5.14 and 5.15 respectively.

*Table 5.13 Creating a caring culture AHP analysis with PV for SQUH*

| **Creating a caring culture** | Decisions according values | Promoting a safe work environment | Promoting a quality culture | P.V |
|---|---|---|---|---|
| Decisions according values | 1 | 1/2 | 1/4 | 0.143 |
| Promoting a safe work environment | 2 | 1 | 1/2 | 0.286 |
| Promoting a quality culture | 4 | 2 | 1 | **0.571** |

Table 5.13 shows the PV values in the *creating a caring culture* sub-module. The values are 0.143 for *decisions according to values*, 0.286 for *promoting a safe work environment* and **0.571** for *promoting a quality culture*. This means that focusing on this sub-module, SQUH's priority should be to rectify the dimension of *promoting a quality culture* before attempting the other two dimensions.

*Table 5.14 Planning and designing AHP analysis with PV for SQUH*

| **Planning and designing** | Planning for community needs | Understanding community health status change | Developing an operational plans | P.V |
|---|---|---|---|---|
| Planning for community needs | 1 | 1/3 | 2 | 0.249 |
| Understanding community health status change | 3 | 1 | 3 | **0.594** |
| Developing an operational plans | 1/2 | 1/3 | 1 | 0.157 |

Table 5.14 indicates the PV values for the *planning and designing* sub-module. The PV values for *planning for community needs, understanding community health status change*, and *developing an operational plan* are 0.249, **0.594**, and 0.157 respectively. Therefore, the priority for SQUH is to focus on this sub-module in order to improve the dimension *understanding community health status change* (this was highlighted because the organisation's information about the community is not maintained in a format that is easy to understand and SQUH's leaders do not share information about the community with the service users) before attempting the *planning for community needs* and *developing an operational plan.*

*Table 5.15 Improving quality AHP analysis with PV for SQUH*

| **Improving quality** | Managing risk | Improving client flow | Improving client safety | Implementing a QM system | P.V |
|---|---|---|---|---|---|
| Managing risk | 1 | 1/2 | 1 | 1/3 | 0.141 |
| Improving client flow | 2 | 1 | 2 | 1/2 | 0.263 |
| Improving client safety | 1 | 1/2 | 1 | 1/3 | 0.141 |
| Implementing a QM system | 3 | 2 | 3 | 1 | **0.455** |

Table 5.15 shows the PV values for the *improving quality* sub-module. The PV values for *managing risk, improving client flow, improving client safety* and *implementing a quality management system* are 0.141, 0.263, 0.141 and **0.455** respectively. Therefore, the priority for SQUH is to focus on in this sub-module in order to improve the dimension *implementing a quality management system* (this was highlighted because the organisation's leaders do not monitor service, unit, or program areas, and outcome measures so as to align with the broader organisational strategic goals and objectives) before attempting the other three dimensions.

The next analysis uses the same AHP process to determine the PV values at the sub-modules' stage of *creating a caring culture, planning and designing, planning for disasters* and *improving quality*. The summary of these sub-modules PV values is tabulated in Table 5.16. The values are **0.467** for *creating a caring culture*, 0.277 for *planning and designing*, 0.095 for *planning for disasters,* and 0.160 for *improving quality*. This means that by focusing on this module, SQUH's priority is to rectify the sub-module of *creating a caring culture,* followed by the sub-module *planning and designing,* then *improving quality,* and finally the sub-module of *planning for disasters.*

*Table 5.16 Level 2: Healthcare Leadership AHP analysis with PV for SQUH*

| **Level 2** | Creating a caring culture | Planning and designing | Planning for disasters | Improving quality | P.V |
|---|---|---|---|---|---|
| Creating a caring culture | 1 | 2 | 4 | 3 | **0.467** |
| Planning and designing | 1/2 | 1 | 3 | 2 | 0.277 |
| Planning for disasters | 1/4 | 1/3 | 1 | 1/2 | 0.095 |
| Improving quality | 1/3 | 1/2 | 2 | 1 | 0.160 |

Table 5.17 summarises the AHP-PV values for each of the dimensions and sub-modules for the *Healthcare Leadership* module. The KB L6σ-QMHE analysis proposes that SQUH first core efforts should be resolving the area of *creating a caring culture* due to the highest PV of **0.467**. The KB L6σ-QMHE also recommends SQUH to improve the *promotion of a quality culture* dimension which has a PV of **0.571**.

The KB L6σ-QMHE analysis recommends that SQUH should then focus on the *planning and designing* sub-module (PV = 0.277) before proceeding to develop *improving quality* and *planning for disasters*. In the *planning and designing* sub-module, more attention has to be given to the *understanding of community health status change* dimension that has a PV of 0.594, similarly in relation to *improving quality* sub-module, SQUH needs to concentrate on *implementing a quality management system* (PV = 0.455).

*Table 5.17 Summary of AHP PV values for Level 2: Healthcare Leadership for SQUH*

| Sub-module | Priority Vector | Dimensions | Priority Vector |
|---|---|---|---|
| **Creating a caring culture** | **0.467** | Decisions according values | 0.143 |
| | | Promoting a safe work environment | 0.286 |
| | | Promoting a quality culture | **0.571** |
| **Planning and designing** | 0.277 | Planning for community needs | 0.249 |
| | | Understanding community health status change | **0.594** |
| | | Developing an operational plans | 0.157 |
| **Planning for disasters** | 0.095 | Preparing for disasters and emergencies | 1.000 |
| **Improving quality** | 0.160 | Managing Risk | 0.141 |
| | | Improving client flow | 0.263 |
| | | Improving client safety | 0.141 |
| | | Implementing a quality management system | **0.455** |

In summary, for Level 2, the KB L6σ-QMHE system analysis has recorded the GAP analysis of 80 BPs from 384 KB rules triggered. This reveals that SQUH's leadership is only 20.83% below the benchmark to fulfil the requirement of full L6σ-QMHE implementation. The KB L6σ-QMHE analysis concludes that SQUH needs to

take action to improve the *promotion of a quality culture* dimension in the *creation of a caring culture* sub-module.

### *5.3.4 Organisation SQUH: Level 3 – Healthcare Organisation's Resources*

This section will show how the *Healthcare Organisation's Resources* Level will help in capturing data about SQUH's human, physical, and technical resources. It will show, also, how the rules implanted in the module will establish relationships, converting these data into information. By assessing or comparing the level of performance of SQUH, the module will convert this information into recommendations about strategic issues in relation to the hospital (knowledge or know-how). *Level 3: Healthcare Organisation's Resources* of the L6σ-QMHE system consists of three sub-modules: *healthcare human resources, healthcare physical capital, and technical resources* as shown in Figure 5.4 and illustrated in Chapter 4.

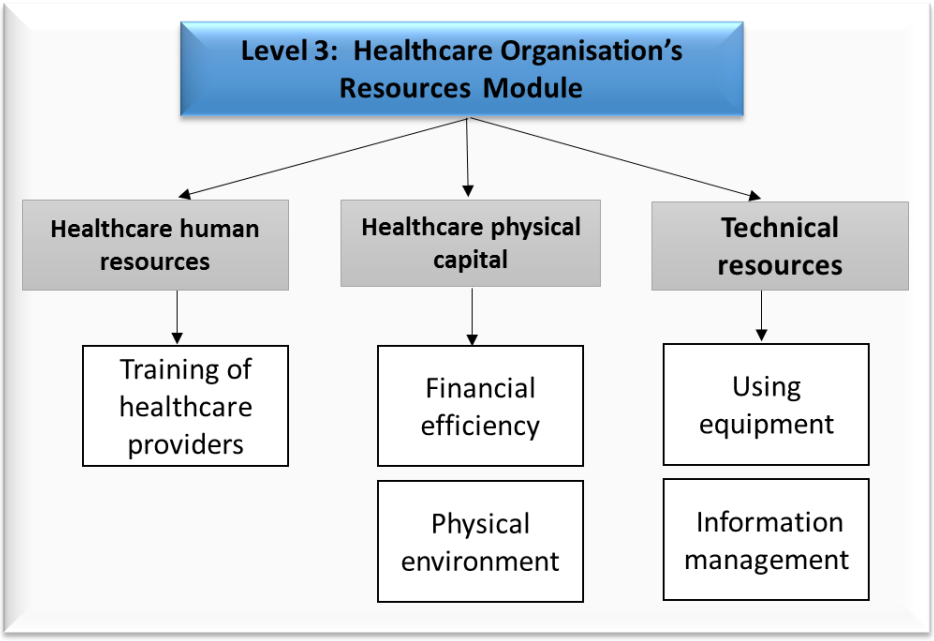


*Figure 5.4 Level 3: Module of Healthcare Organisation's Resources*

This module contains a total of 141 KB rules that were developed for knowledge base. Based on the answers from the users in SQUH, the GAP analysis results of *Level 3: Healthcare Organisation's Resources* has been summarised and tabulated, as seen in Table 5.18. These results reflect the difference between the existing practice and the benchmarked practice. As noted earlier, there have been a total of 141 KB rules triggered in this module which include a number of GPs, and a number of BPs rated as PCs from PC-1 to PC-5. The optimisation technique (GAP analysis) in this research suggests that only the BPs are categorised as PC in order to find out the requisites for further improvements. Out of 141 KB rules triggered, the system has categorised 96 as GPs and the remaining 45 as BPs. The 45 BPs are classified into different PCs (0 for PC-1, 6 were in PC-2, 12 in PC-3, 27 in PC-4, and 0 for PC-5). Although, KB L6σ-QMHE has proven that SQUH does not have any BPs in PC-1, but it still needs to fill the gaps in other PCs to fulfil the requirements of full L6σ-QMHE implementation.

*Table 5.18 GAP analysis results of SQUH resources*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Human resources** | Training of Healthcare providers | **54** | **22** | **32** | **0** | **4** | **11** | **17** | **0** |
| | **Sub-total** | **54** | **22** | **32** | **0** | **4** | **11** | **17** | **0** |
| **Physical capital** | Financial efficiency | **22** | **18** | **4** | **0** | **2** | **0** | **2** | **0** |
| | Physical environment | **21** | **21** | **0** | **0** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **43** | **39** | **4** | **0** | **2** | **0** | **2** | **0** |
| **Technical resources** | Using equipment | **20** | **13** | **7** | **0** | **0** | **1** | **6** | **0** |
| | Information management | **24** | **22** | **2** | **0** | **0** | **0** | **2** | **0** |
| | **Sub-total** | **44** | **35** | **9** | **0** | **0** | **1** | **8** | **0** |
| **Total** | | **141** | **96** | **45** | **0** | **6** | **12** | **27** | **0** |

In the *human resources* sub-module, a total of 54 KB rules were asked of which 22 were GPs. However, there were 32 KB rules, which were not met (BPs), representing

a gap in requisites for accomplishing the benchmark. An analysis of these BPs shows that all the key BPs were in the dimension of *training of healthcare providers*. The analysis also shows that the leaders in the hospital do not conduct exit interviews to improve staffing, retention and performance. Thus, the hospital has to focus on correcting the problems from category 4 PC-2 before fixing the others i.e. 11 PC-3 and 17 PC-4.

In the *healthcare physical capital* sub-module, a total of 43 KB rules were asked of which 39 were GPs. However, there were 4 KB rules, which were not met (BPs), representing a gap in the requisites for accomplishing the benchmark. An analysis of these BPs shows that all key BPs were in the dimension of *financial efficiency*. A key aspect from this analysis reveals that with this dimension there were 4 BPs (2 in PC-2 and 2 in PC-4). The analysis also shows that this is a significant factor that can negatively affect the physical capital. Furthermore, analysis reveals that when hospital's governing body makes decisions relating to resources allocation, the leaders do not evaluate the cost effectiveness to all services provided.

In the *technical resources* sub-module, a total of 44 KB rules were asked of which 35 were GPs. However, there were 9 KB rules, which were not met (BPs), representing a gap in the requisites for accomplishing the benchmark. An analysis of these BPs shows that major key BPs were in the dimension of *using equipment*. A key aspect from this analysis reveals that there were 7 BPs in relation to this dimension (1in PC-3 and 6 in PC-4). These results are considered to be a significant and can negatively affect the use of equipment. The analysis further shows that the leaders in the hospital do not have a process to evaluate the effectiveness of the preventive maintenance program.

As mentioned in previous levels, the above GAP analysis has been used by the KB L6σ-QMHE system to produce the AHP analysis. This step is very important as it

determines which aspects should be prioritised for further improvements. The integrated AHP will start the analysis by determining the values of PVs in each sub-module. For the sub-modules *physical capital* and *technical resources*, the PV values of each dimension have been calculated as represented in Tables 5.19 and 5.20 respectively.

*Table 5.19 Physical capital AHP analysis with PV for SQUH*

| **Physical capital** | Financial efficiency | Physical environment | P.V |
|---|---|---|---|
| Financial efficiency | 1 | 2 | **0.667** |
| Physical environment | 1/2 | 1 | 0.333 |

Table 5.19 shows the PV values in the *physical capital* sub-module. The values are **0.667** for *financial efficiency* and 0.333 for *physical environment.* This means that focusing on this sub-module, SQUH's priority should be to rectify the dimension of *financial efficiency* before attempting the other dimension.

*Table 5.20 Technical resources AHP analysis with PV for SQUH*

| **Technical resources** | Using equipment | Information management | P.V |
|---|---|---|---|
| Using equipment | 1 | 2 | **0.667** |
| Information management | 1/2 | 1 | 0.333 |

Table 5.20 indicates the PV values for the *technical resources* sub-module. The PV values for *using equipment* and *information management* are **0.667** and 0.333 respectively. Therefore, the priority for SQUH should be to focus on this sub-module in order to improve the dimension *using equipment* (this was highlighted because the organisation's leaders do not have a process to evaluate the effectiveness of the preventive maintenance program and they partially verify if plans or processes for replacing medical devices and equipment are followed) before attempting the *information management.*

The next analysis uses the same AHP process to determine the PV values at the sub-modules' stage of *human, physical capital,* and *technical resources*. The summary of these sub-modules PV values is tabulated, as seen in Table 5.21. The values are **0.50** for *human resources*, 0.25 for *physical capital*, and 0.25 for *technical resources*. This means that by focusing on this module, SQUH's priority should be to rectify the sub-module of *human resources,* followed by the sub-modules *physical capital* and *technical resources.*

*Table 5.21 Level 3: Healthcare Organisation's Resources AHP analysis with PV for SQUH*

| **Level 3** | Human resources | Physical capital | Technical resources | P.V |
|---|---|---|---|---|
| Human resources | 1 | 2 | 2 | **0.50** |
| Physical capital | 1/2 | 1 | 1 | 0.25 |
| Technical resources | 1/2 | 1 | 1 | 0.25 |

Table 5.22 summarises the AHP-PV values for each of the dimensions and sub-modules for the *Healthcare Organisation's Resources* module. The KB L6σ-QMHE analysis proposes that SQUH first core effort should be in resolving the area of *human resources* because of the high PV of 0.50.

The KB L6σ-QMHE analysis recommends that SQUH should then focus equally on the *physical capital* sub-module (PV = 0.25) and *technical resources* sub-module (PV = 0.25). In the *physical capital* sub-module, more attention should be given to the *financial efficiency* dimension that has a PV of 0.667, similarly in the *technical resources* sub-module, SQUH needs to concentrate on the *use of equipment* (PV = 0.667).

*Table 5.22 Summary of AHP PV values for Level 3: Healthcare Organisation's Resources for SQUH*

| Sub-module | Priority Vector | Dimensions | Priority Vector |
|---|---|---|---|
| **Human resources** | **0.50** | Training of Healthcare providers | 1.0 |
| **Physical capital** | 0.25 | Financial efficiency | **0.667** |
| | | Physical environment | 0.333 |
| **Technical resources** | 0.25 | Using equipment | **0.667** |
| | | Information management | 0.333 |

In summary, for Level 3, the KB L6σ-QMHE system analysis has recorded the GAP analysis of 45 BPs from 141 KB rules triggered. This reveals that SQUH's resources management is 31.91% below the benchmark of fulfilling the requirements of full L6σ-QMHE implementation at this level. The KB L6σ-QMHE analysis concludes that SQUH needs to take action to improve the *human resources* sub-module.

### *5.3.5 Organisation SQUH: Level 4 – Healthcare L6σ Implementation*

This section will show how the *Healthcare L6σ Implementation* Level helps in capturing data about the pre-implementation and evaluation of L6σ in SQUH. It will show how the rules implanted in the module will establish relationships, converting this data into information. By assessing or comparing the level of performance in SQUH, the module will convert this information into recommendations about strategic issues in the hospital (knowledge or know-how). The *Level 4: Healthcare L6σ Implementation* of the L6σ-

QMHE system consists of two sub-modules: *pre-implementation L6σ* and *evaluation of L6σ* as shown in Figure 5.5 and illustrated in Chapter 4.

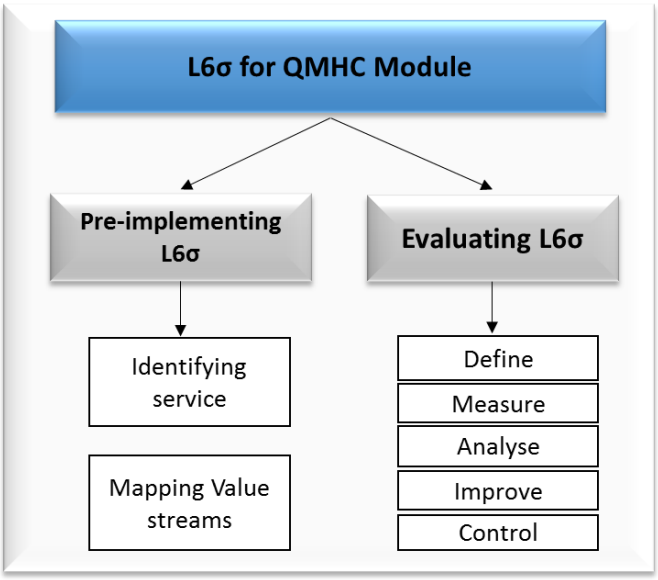


*Figure 5.5 Level 4: Module of L6σ for QMHE*

This module contains a total of 112 KB rules that have been developed for the knowledge base. Based on the answers from the users in SQUH, the GAP analysis results of *Level 4: Healthcare L6σ Implementation* was summarised and tabulated, as seen in Table 5.23. These results reflect the difference between the existing practice and the benchmarked practice. There have been a total of 112 KB rules triggered in this module which include the number of GPs, and the number of BPs rated as PCs from PC-1 to PC-5. As discussed earlier, the optimisation technique (GAP analysis) in this research suggests that only the BPs are categorised as PC in order to find out the requisites for further improvements. Out of 112 KB rules triggered, the system has categorised 33 as GPs and the remaining 79 as BPs. The 79 BPs are classified into different PCs (0 for PC-1, 29 in PC-2, 32 in PC-3, 18 in PC-4, and 0 for PC-5). Although, KB L6σ-QMHE has proven that SQUH do not have any BPs in PC-1, it however needs to fill the gaps in other PCs to fulfil the requirements of full L6σ-QMHE implementation.

*Table 5.23 GAP analysis results of SQUH L6σ of Quality Management at Healthcare*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Pre-implementing L6σ** | Identifying service | **27** | **6** | **21** | **0** | **5** | **1** | **15** | **0** |
| | Mapping value streams | **41** | **14** | **27** | **0** | **6** | **19** | **2** | **0** |
| | **Sub-total** | **68** | **20** | **48** | **0** | **11** | **20** | **17** | **0** |
| **Evaluating L6σ** | Define | **16** | **8** | **8** | **0** | **0** | **7** | **1** | **0** |
| | Measure | **10** | **0** | **10** | **0** | **10** | **0** | **0** | **0** |
| | Analyse | **5** | **1** | **4** | **0** | **4** | **0** | **0** | **0** |
| | Improve | **6** | **1** | **5** | **0** | **3** | **2** | **0** | **0** |
| | Control | **7** | **3** | **4** | **0** | **1** | **3** | **0** | **0** |
| | **Sub-total** | **44** | **13** | **31** | **0** | **18** | **12** | **1** | **0** |
| **Total** | | **112** | **33** | **79** | **0** | **29** | **32** | **18** | **0** |

In the *pre-implementation L6σ* sub-module, a total of 68 KB rules were triggered of which 20 were GPs (meaning that the requisites for these were met). However, there were 48 KB rules, which were not met (BPs), indicating a gap in the requisites for achieving the benchmark. A further analysis of these BPs shows that major key BPs were in both dimensions of *identifying services,* and *mapping value stream*. A key aspect from this analysis reveals that in relation to the dimension *identifying services* (21 were BPs, of which 5 are in PC-2, 1in PC-3, and 15 in PC-4). The analysis further reveals that this can negatively affect the success of L6σ projects in SQUH.

Additionally in the same sub-module, *mapping value stream* dimension has 27 BPs (6 in PC-2, 19 in PC-3, and 2 in PC-4). Basically, these results show that SQUH's L6σ champion with the executive team do not gather basic information about the current status of the organisation and do not outline areas of the organisation that are more amenable to L6σ compared to others. The analysis also shows that the leaders of the organisation do not take into account the study of how the need and benefits of L6σ effort should be communicated to others. These leaders also do not create a solid picture of how

people survive differently under the L6σ. Hence, SQUH has to focus on rectifying the problems from category 11 PC-2 before fixing the other 37 PCs (20 PC-3 and 17 PC-4).

In the *evaluation of L6σ* sub-module, a total of 44 KB rules were triggered of which 13 were GPs. However, there were 31 KB rules, which were not met (BPs), indicating a gap in pre-requisites for achieving benchmark. An analysis of these BPs shows that key BPs were in the dimensions of *Measure*, and *Define*. A critical aspect from this analysis reveals that in relation to the *Measure* dimension there were 10 BPs in PC-2. These results indicate that L6σ team does not monitor work in process as part of baselines metrics establishment as well as does not use control charts (or any other tool) to describe the variation in the process. Additionally, the analysis of the dimension *Define* shows that there were 8 BPs (7 in PC-3 and 1in PC-4). These BPs exist due to lack of understanding the project's link to business strategy and knowing what indicators will be used to assess accomplishment.

As mentioned before, the above GAP analysis has been used by the KB L6σ-QMHE system to produce the AHP analysis. This step is very important as it determines which aspects should be prioritised for further improvements. The integrated AHP will start the analysis by determining the values of PVs in each sub-module. For the sub-modules *pre-implementing L6σ and evaluating L6σ*, the PV values of each dimension have been calculated as represented in Tables 5.24 and 5.25 respectively.

*Table 5.24 Pre-implementing L6σ AHP analysis with PV for SQUH*

| **Pre-implementing L6σ** | Identifying service | Mapping value streams | P.V |
|---|---|---|---|
| Identifying service | 1 | 1/2 | 0.333 |
| Mapping value streams | 2 | 1 | **0.667** |

Table 5.24 shows the PV values in the *pre-implementing L6σ* sub-module. The values are 0.333 for *identifying service* and **0.667** for *mapping value streams.* This means that focusing on this sub-module, SQUH's priority should be to rectify the dimension of *mapping value streams* before attempting the other dimension.

*Table 5.25 Evaluating L6σ AHP analysis with PV for SQUH*

| **Evaluating L6σ** | Define | Measure | Analyse | Improve | Control | P.V |
|---|---|---|---|---|---|---|
| Define | 1 | 1/2 | 3 | 2 | 4 | 0.271 |
| Measure | 2 | 1 | 4 | 3 | 4 | **0.406** |
| Analyse | 1/3 | 1/4 | 1 | 1 | 1/2 | 0.090 |
| Improve | 1/2 | 1/3 | 1 | 1 | 2 | 0.134 |
| Control | 1/4 | 1/4 | 2 | 1/2 | 1 | 0.099 |

Table 5.25 shows the PV values for the *evaluating L6σ* sub-module. The PV values for *Define, Measure, Analyse, Improve and Control* are 0.271, **0.406**, 0.090, 0.134 and 0.099 respectively. Therefore, the priority for SQUH is to focus on this sub-module in order to improve the dimension *Measure* (this was highlighted because the L6σ team does not monitor Work in Process as part of baselines metrics establishment as well as monitor average completion rate) before attempting the other dimensions.

The next analysis uses the same AHP process to determine the PV values at the sub-modules' stage of *pre-implementing L6σ and evaluating L6σ.* The summary of these sub-modules PV values is tabulated in Table 5.26. The values are **0.667** for *pre-implementing L6σ* and 0.333 for *evaluating L6σ.* This means that by focusing on this module, SQUH's priority will be to rectify the sub-module of *pre-implementing L6σ,* followed by the sub-module *evaluating L6σ.*

*Table 5.26 Level 4: L6σ of Quality Management at Healthcare AHP analysis with PV for SQUH*

| **Level 4** | Pre-implementing L6σ | Evaluating L6σ | P.V |
|---|---|---|---|
| Pre-implementing L6σ | 1 | 2 | **0.667** |
| Evaluating L6σ | 1/2 | 1 | 0.333 |

Table 5.27 summarises the AHP-PV values for each of the dimensions and sub-modules for the *L6σ of Quality Management at Healthcare* module. The KB L6σ-QMHE analysis proposes that SQUH's first core effort should be in resolving the area of *pre-implementing L6σ* due to the highest PV of **0.667**. The KB L6σ-QMHE also recommends SQUH to improve the *mapping value streams* dimension which has a PV of 0.667.

The KB L6σ-QMHE analysis recommends that SQUH should then focus on the *evaluating L6σ* sub-module (PV = 0.333). In this sub-module, more attention has to be given to the *Measure* dimension because of its PV of **0.406** and then rectify the *Define* dimension (PV=0.271). After that, it needs to focus on the *Improve* dimension (PV=0.134), *Control* dimension (PV=0.099) and finally, *Analyse* dimension (PV=0.090).

*Table 5.27 Summary of AHP PV values for Level 4: L6σ of Quality Management at Healthcare for SQUH*

| **Sub-module** | **Priority Vector** | **Dimensions** | **Priority Vector** |
|---|---|---|---|
| **Pre-implementing L6σ** | **0.667** | Identifying service | 0.333 |
| | | Mapping value streams | **0.667** |
| **Evaluating L6σ** | 0.333 | Define | 0.271 |
| | | Measure | **0.406** |
| | | Analyse | 0.090 |
| | | Improve | 0.134 |
| | | Control | 0.099 |

In summary, for Level 4, the KB L6σ-QMHE system analysis has recorded the GAP analysis of 79 BPs from 112 KB rules triggered. This reveals that L6σ's team in SQUH is 70.53% below the benchmark to fulfil the requirement of full L6σ-QMHE implementation. The KB L6σ-QMHE analysis concludes that SQUH needs to take action to improve the *mapping value streams* dimension in the *pre-implementing L6σ* sub-module.

## 5.4 Organisation SQUH: Validation Discussion of KB L6σ-QMHE system

As discussed for each module in Section 5.3, this section will summarise the results analysis at SQUH based on the applied validation process.

### *5.4.1 Summarised KB L6σ-QMHE Output for Organisation SQUH*

Based on the KB L6σ-QMHE system analysis, Table 5.28 illustrates the summarised results for SQUH. In total 964 KB rules were triggered in these modules – the output shows 612 GPs representing the GPs of SQUH in implementing L6σ-QMHE, however, 352 BPs were identified by the system based on the SQUH user feedback, which demonstrates the overall organisation performance is about 36.5% lower than the designed benchmark. Similarly, the KB L6σ-QMHE system has considered categories PC-1 and PC-2 as the major problematic areas, whereas category PC-3 and above are minor problems. Obviously, it can be seen from Table 5.28 that SQUH has 14.6% of the BPs as major problematic areas and 21.9% of the BPs as minor problems. The detailed breakdown of the modules' (Level 0–Level 4) BP percentages can be highlighted in ratios (serious: unserious) as 76.5% (27.8:48.7), 28.3% (24.5:3.8), 20.9% (5.7:15.2), 31.9% (4.3:27.6), and 70.5% (25.9:44.6) respectively.

*Table 5.28 Summary of GAP Analysis Results for SQUH*

| Level | Sub-module | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Level 0: Healthcare Organisation's Environment** | Healthcare Organisation's Statement | **52** | **26** | **26** | **13** | **5** | **8** | **0** | **0** |
| | Healthcare Quality Dimensions | **63** | **1** | **62** | **0** | **14** | **9** | **39** | **0** |
| | **Sub-total** | **115** | **27** | **88** | **13** | **19** | **17** | **39** | **0** |
| | **Percentage (%)** | | **23.5** | **76.5** | **27.8** | | **48.7** | | |
| **Level 1: Healthcare Governance** | Effective Governing Body | **93** | **81** | **12** | **8** | **4** | **0** | **0** | **0** |
| | Supporting | **54** | **44** | **10** | **10** | **0** | **0** | **0** | **0** |
| | Sustainable Results | **65** | **27** | **38** | **8** | **22** | **8** | **0** | **0** |
| | **Sub-total** | **212** | **152** | **60** | **26** | **26** | **8** | **0** | **0** |
| | **Percentage (%)** | | **71.7** | **28.3** | **24.5** | | **3.8** | | |
| **Level 2: Healthcare Leadership** | Creating a caring culture | **112** | **70** | **42** | **0** | **9** | **17** | **16** | **0** |
| | Planning and designing | **160** | **133** | **27** | **0** | **8** | **16** | **3** | **0** |
| | Planning for disasters | **44** | **44** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Improving quality | **68** | **57** | **11** | **0** | **5** | **3** | **3** | **0** |
| | **Sub-total** | **384** | **304** | **80** | **0** | **22** | **36** | **22** | **0** |
| | **Percentage (%)** | | **79.1** | **20.9** | **5.7** | | **15.2** | | |
| **Level 3: Healthcare Organisation's Resources** | Human resources | **54** | **22** | **32** | **0** | **4** | **11** | **17** | **0** |
| | Physical Capital | **43** | **39** | **4** | **0** | **2** | **0** | **2** | **0** |
| | Technical resources | **44** | **35** | **9** | **0** | **0** | **1** | **8** | **0** |
| | **Sub-total** | **141** | **96** | **45** | **0** | **6** | **12** | **27** | **0** |
| | **Percentage (%)** | | **68.1** | **31.9** | **4.3** | | **27.6** | | |
| **Level 4: L6σ for QMHE** | Pre-implementing L6σ | **68** | **20** | **48** | **0** | **11** | **20** | **17** | **0** |
| | Evaluating L6σ | **44** | **13** | **31** | **0** | **18** | **12** | **1** | **0** |
| | **Sub-total** | **112** | **33** | **79** | **0** | **29** | **32** | **18** | **0** |
| | **Percentage (%)** | | **29.5** | **70.5** | **25.9** | | **44.6** | | |
| **Grand Total** | | **964** | **612** | **352** | **39** | **102** | **105** | **106** | **0** |
| **Percentage (%)** | | | **63.5** | **36.5** | **14.6** | | **21.9** | | |

As Table 5.29 shows, at *Level 0: Healthcare Organisation's Environment*, the most serious problems were identified in the *healthcare quality dimensions* sub-module and specifically in the *patient-centred* dimension. The second problematic sub-module is the *healthcare organisation's statement*, where lack of records has been triggered in the *vision* aspect with regards to identifying timeframes for achieving the strategic goals of

the organisation. This has caused a gap in the governing body's overseeing a strategic planning process to develop the organisation's vision and set the strategic plan, goals, and objectives.

Based on the output results of *Level 1: Healthcare Governance,* the most critical part was the *sustainable results* sub-module. The *promoting quality improvement* dimension has proved that SQUH's governing body does not ensure risk management approach plans are in place in the organisation. The second serious sub-module at *Level 1* is *effective governing body*. The analysis shows that SQUH's governing body does not regularly review its roles and responsibilities. The least important sub-module at this level is *supporting.* The analysis has shown a gap in reviewing the frequency of adverse events and near misses as part of the organisation's quarterly client safety reports.

At *Level 2: Healthcare Leadership,* the most serious problems were identified in *creating a caring culture* sub-module and specifically in the *promoting of a quality culture* dimension. The second problematic sub-module is the *planning and designing***,** where lack of *understanding community health status change* has shown to be part of the user's output. This has caused a gap between the governing body and the organisation's leaders in exchanging information about the community. The next important sub-module at this level is *improving quality.* The analysis has shown a gap in implementing quality management system in terms of monitoring service, unit, or program areas to monitor their own process and outcome measures which aligns with the broader organisational strategic goals and objectives. In *planning for disasters* sub-module, SQUH has achieved 100% of the KB L6σ-QMHE system requirement in accordance to the user's output.

Moving to *Level 3: Healthcare Organisation's Resources,* the most critical part was the *human resources* sub-module. Some gaps were identified in the training of

healthcare providers, defining their roles for client safety, writing and using exit interviews' information to improve performance. *Physical Capital* and *technical resources* dimensions are equally the second serious sub-modules at *Level 3*. However, *technical resources* has more BPs compared to *physical capital.* The analysis shows that SQUH's leaders do not manage the physical environment to promote client and staff health and safety. They do not have a process to evaluate the effectiveness of the preventive maintenance program in the organisation.

Lastly, at *Level 4: L6σ for Quality Management at Healthcare*, the key sub-module identified by the system was *pre-implementing L6σ* in which a remarkable gap was created in the dimension of *mapping value streams*. In fact, SQUH's leaders do not know why they are implementing strategies built on L6σ philosophies as a quality improvement tool. Moreover, the governing body and executive team do not determine the gaps between present and wanted performance. The second serious sub-module at this level is *evaluating L6σ.* Based on the output results of this sub-module, the most critical dimension was *Measure*, where L6σ team do not use any value stream maps (or any other tool) to describe the process nor any control charts (or any other tool) to describe the variation in the process.

*Table 5.29 Summary of AHP-PV values for Organisation SQUH*

| Level | Sub-module | PVs | Dimensions with PVs | | | | |
|---|---|---|---|---|---|---|---|
| **Level 0:** Healthcare Org.'s Env. | Healthcare Organisation's Statement | 0.333 | Vision (**0.50**) | Mission (0.25) | | Values (0.25) | |
| | Healthcare Quality Dimensions | **0.667** | Accessibility (0.245) | Patient-centred (**0.463**) | | Effectiveness (0.292) | |
| **Level 1:** Healthcare Governance | Effective Governing Body | 0.297 | Roles and responsibilities (**0.571**) | Membership (0.286) | | Decision making (0.143) | |
| | Supporting | 0.163 | Evaluating the CEO (0.20) | Financial planning (0.20) | | Supporting patient safety culture (**0.60**) | |
| | Sustainable Results | **0.540** | Relations with community (0.124) | Promoting quality improvement (**0.517**) | | Monitoring performance (0.359) | |
| **Level 2:** Healthcare Leadership | Creating a caring culture | **0.467** | Decisions according values (0.143) | Promoting a safe work environment (0.286) | | Promoting a quality culture (**0.571**) | |
| | Planning and designing | 0.277 | Planning for community needs (0.249) | Understanding community health status change (**0.594**) | | Developing an operational plans (0.157) | |
| | Planning for disasters | 0.095 | Preparing for disasters and emergencies | | | | |
| | Improving quality | 0.160 | Managing Risk (0.141) | Improving client flow (0.263) | Improving client safety (0.141) | Implementing a quality management system (**0.455**) | |
| **Level 3:** Healthcare Org.'s Resources | Human resources | **0.50** | Training of Healthcare providers | | | | |
| | Physical Capital | 0.25 | Financial efficiency (**0.667**) | | | Physical environment (0.333) | |
| | Technical resources | 0.25 | Using equipment (**0.667**) | | | Information management (0.333) | |
| **Level 4:** L6σ for QMHE | Pre-implementing L6σ | **0.667** | Identifying service (0.333) | | | Mapping value streams (**0.667**) | |
| | Evaluating L6σ | 0.333 | Define (0.271) | Measure (**0.406**) | Analyse (0.090) | Improve (0.134) | Control (0.099) |

The KB L6σ-QMHE is embedded within AHP, which also supports SQUH in prioritising its decisions, by facilitating the PV values for each and every part of the system. Table 5.29 illustrates the PV values for each module (Level 0–Level 4), which

were used to formulate the developed KB L6σ-QMHE framework with the critical areas highlighted.

*5.4.1.1 Priority 1 Improvements for Organisation SQUH*

The developed KB L6σ-QMHE framework shown in Figure 5.7 illustrates a Priority 1 visual improvement roadmap for SQUH prioritised by the KB-AHP-GAP System. Starting from the strategic levels, the AHP aspect of the KB System has the highest priority (1) at *Level 0: Healthcare Organisation's Environment* that SQUH should improve on. Within this module, the sub-module *healthcare quality dimensions* has been identified as the key where the *patient-centred* dimension plays a major role.

Thereafter, at *Level 1: Healthcare Governance*, the KB System has identified the sub-module *sustainable results* as Priority 1, specifically within the dimension of *promoting quality improvement*, (by ensuring that risk management approach plans are in place in the organisation). Then, at *Level 2: Healthcare Leadership*, the KB System recommends SQUH to start improvements with *creating a caring culture* sub-module, in which the *promoting a quality culture* dimension has identified unavailability of monitoring service processes and outcomes measures which aligns with the broader organisational strategic goals and objectives.

Next, at *Level 3: Healthcare Organisation's Resources*, the KB System has identified the sub-module *human resources* as Priority 1, where SQUH should give more attention for training healthcare providers and defining their roles in relation to client safety in writing. Finally, at *Level 4: L6σ for Quality Management at Healthcare*, the KB System recommends SQUH to start improvements with the *pre-implementing L6σ* sub-module, in which the *mapping value streams* dimension has identified the lack of knowledge in implementing strategies built on L6σ philosophies as a quality improvement tool.

One of the important aspects of this developed KB System is to have a complete audit trail of the KB rules that have identified and prioritised actions for improvement by the AHP and GAP methodologies in order to achieve the benchmark. Hence, Figure 5.6 shows the KB System's prioritised audit trail (Priority 1) in detail, which can be used to assist with decision making, and to develop an action plan for SQUH across the whole organisation (Level 0–Level 4), in order to achieve the benchmark.

In this case, it is recommended to start with the *patient-centred* dimension at Level 0, followed by the *promoting quality improvement* dimension at Level 1, followed by the *promoting a quality culture* dimension at Level 2, followed by the *training healthcare providers* dimension at Level 3, and completed by the *mapping value streams* dimension at Level 4. It can be treated in a step-by-step manner as shown and described above, bearing in mind the immediate actions to be taken for the most serious problems which represent 14.6% of the BPs.

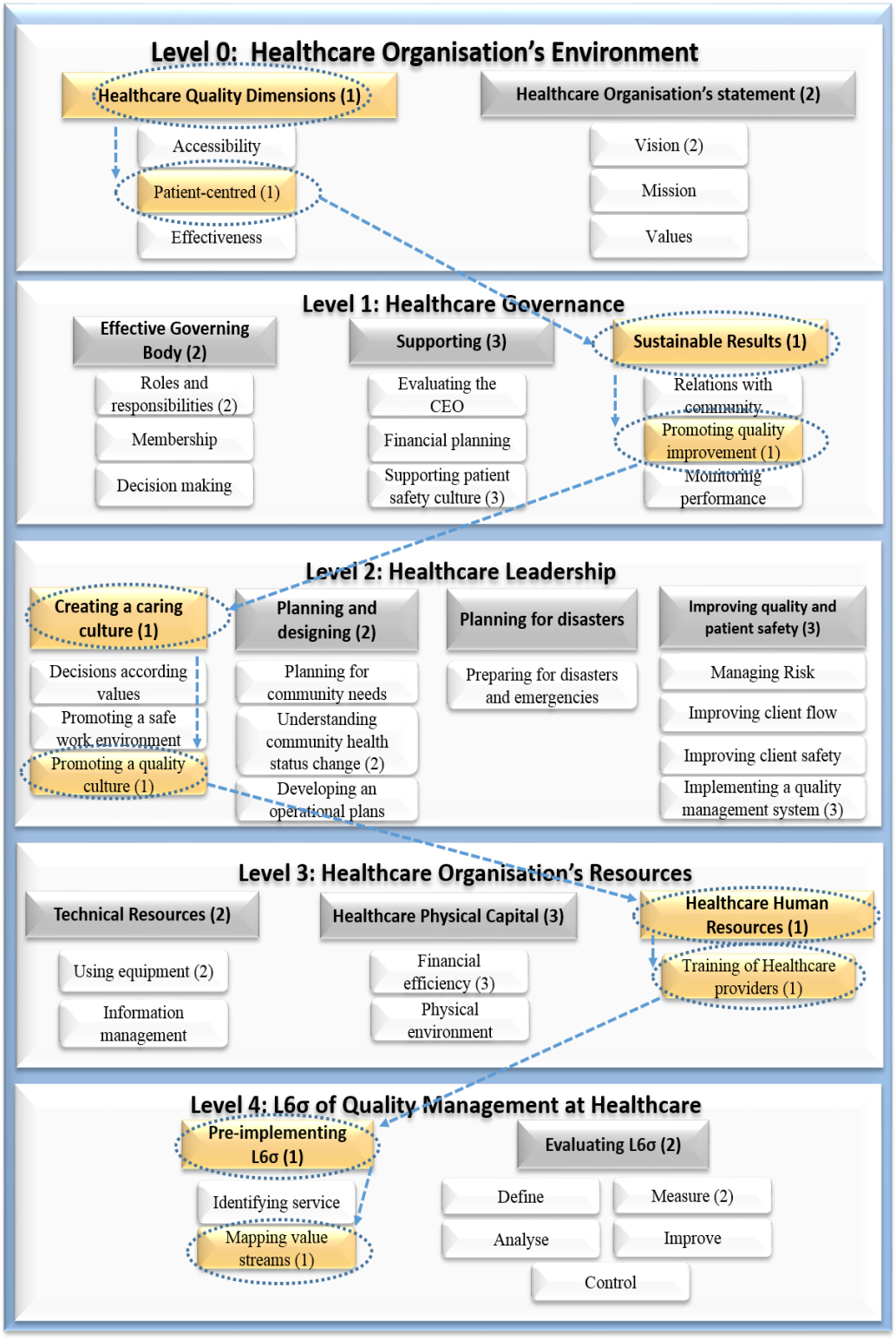


*Figure 5.6 Priority 1 Organisation SQUH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 1 and the audit trail of the rules, Figure 5.7 illustrates the key sub-modules, dimensions, and priority rules across all levels for improvements to achieve the benchmark in SQUH. For the sake of briefness, only PC-1

and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified, and which require action.

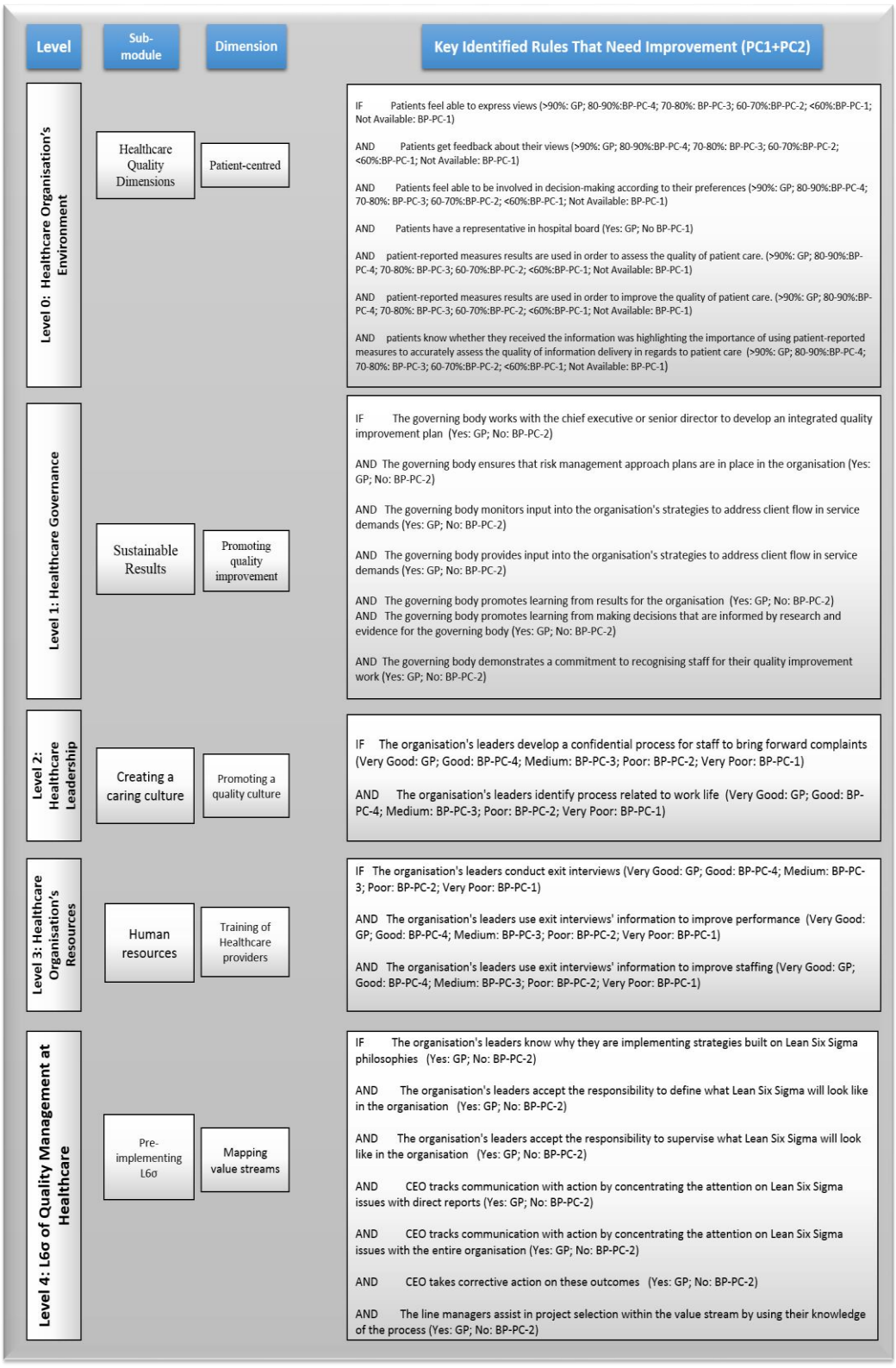


*Figure 5.7 Priority 1 Improvements Actions Identified by KB L6σ-QMHE System for Organisation SQUH*

The above figure of the identified key rules shows that SQUH has to involve patients and their families in the decision-making process and accordance to their

preferences. Besides not promoting quality improvement effectively, this may give an indication that the organisation's culture is below the standard of promoting a patient safety and quality culture among its staff. In the same vein, SQUH should focus on training healthcare providers and defining their roles for client safety in writing. Finally, it has to identify ways to improve Mapping value streams that affect L6σ projects dramatically.

*5.4.1.2 Priority 2 Improvements for Organisation SQUH*

The developed KBL6σ-QMHE framework shown in Figure 5.8 illustrates a Priority 2 visual improvement roadmap for SQUH prioritised by the KB-AHP-GAP System. Starting from the strategic levels, the AHP aspect of the KB System has the second priority at *Level 0: Healthcare Organisation's Environment* that SQUH should improve on. Within this module, the sub-module *healthcare organisation's statement*, is considered to be the Priority 2, where lack of records has been triggered in the *vision* aspect with regards to identifying timeframes for achieving the strategic goals of the organisation.

Thereafter, at *Level 1: Healthcare Governance*, the KB System has identified the sub-module *effective governing body* as Priority 2, specifically within the dimension of *roles and responsibilities*. Then, at *Level 2: Healthcare Leadership*, the second problematic sub-module is the *planning and designing***,** where lack of *understanding community health status change* has shown to affect the user's output. This has caused a gap between the governing body and the organisation's leaders in exchanging information about the community.

Next, *Level 3: Healthcare Organisation's Resources*, the KB System has identified the sub-module *technical resources* as Priority 2, specifically within the dimension of *using equipment* (where the process of evaluating the effectiveness of the

preventive maintenance program in the organisation is not available). Finally, in *Level 4: L6σ for Quality Management at Healthcare*, the second KB System recommendation is the *evaluation of L6σ* sub-module, in which the *Measure* dimension has identified lack of knowledge in using value stream in measuring the defined project by the L6σ team.

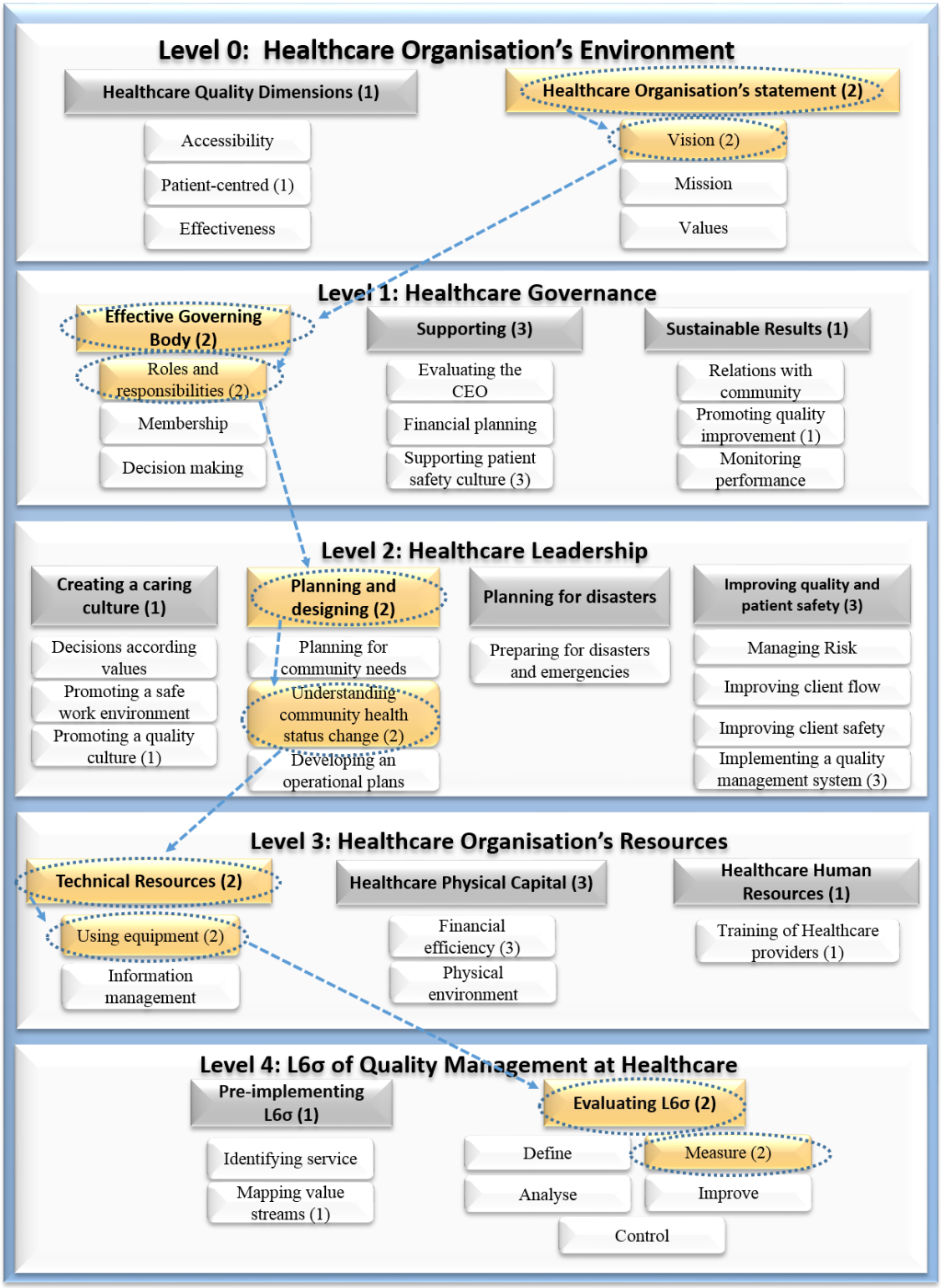


*Figure 5.8 Priority 2 Organisation SQUH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 2 and the audit trail of the rules, Figure 5.9 illustrates the key sub-modules, dimensions, and priority rules across all levels for

improvements to achieve the benchmark in SQUH. Again, for the sake of brevity, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which requires action.

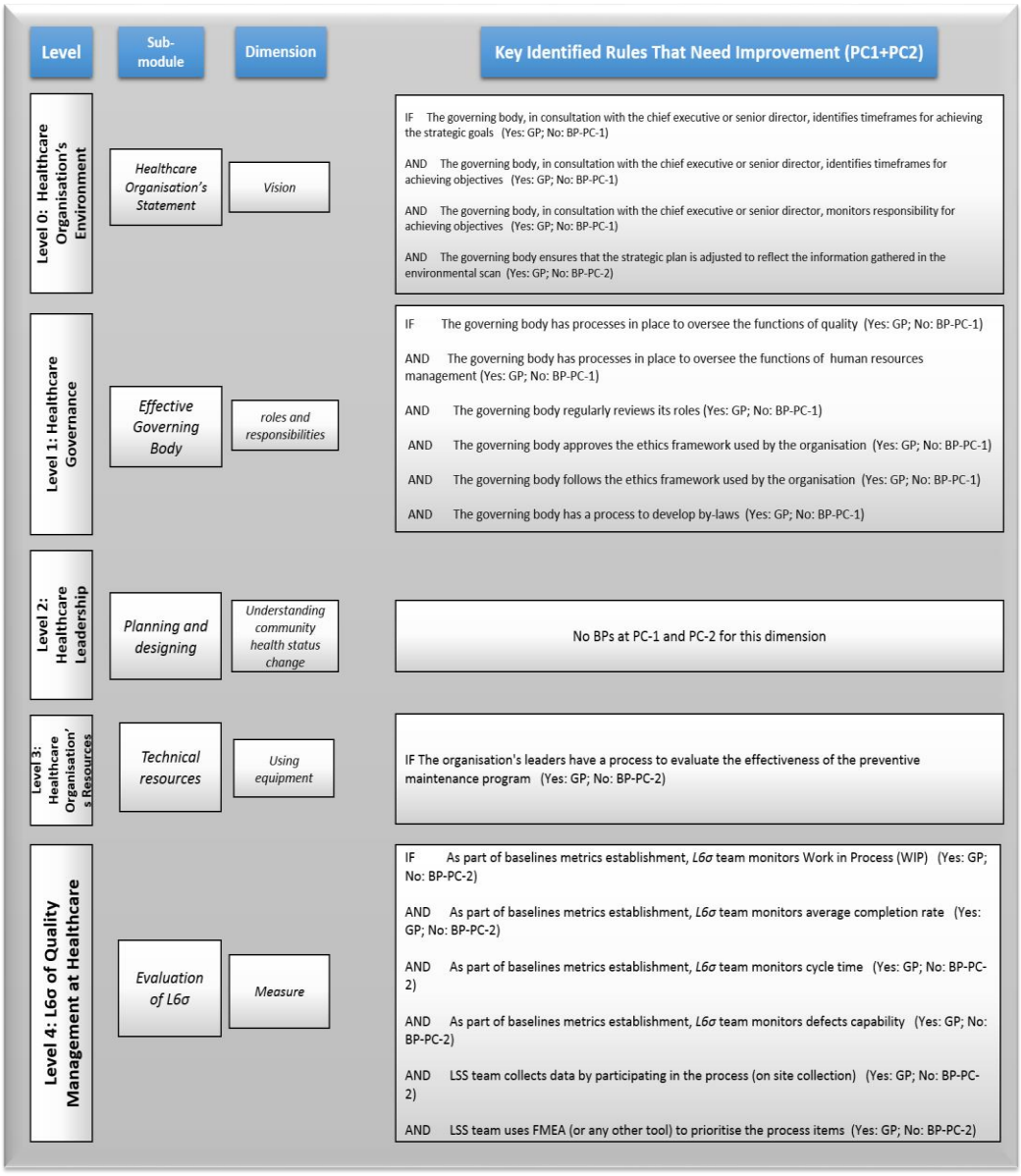


*Figure 5.9 Priority 2 Improvements Actions Identified by KB L6σ-QMHE System for Organisation SQUH*

It can be seen in the figure above that the KB System has not identified any critical issue for Priority 2 improvements in *understanding community health status change* dimension. However, there were still some KB rules that have been detected (7 in PC-3)

by the AHP aspect which might not cause any problem in the short term. Nevertheless, neglecting the same may cascade to future leadership implications. Therefore, it is recommended that these gaps be addressed in order to achieve the L6σ-QMHE benchmark.

*5.4.1.3 Priority 3 Improvements for Organisation SQUH*

The developed KBL6σ-QMHE framework shown in Figure 5.10 illustrates a Priority 3 visual improvement roadmap for SQUH prioritised by the KB-AHP-GAP System. At *Level 1: Healthcare Governance*, the KB System has identified the sub-module *supporting* as Priority 3, specifically within the dimension of *supporting patient safety culture*. Then, at *Level 2: Healthcare Leadership,* the third problematic sub-module is the *improving quality***,** where it shows a gap in *implementing quality management system* in terms of monitoring service, unit, or program areas to monitor their own process and outcome measures that align with the broader organisational strategic goals and objectives.

Finally, at *Level 3: Healthcare Organisation's Resources*, the KB System has identified the sub-module *physical capital* as Priority 3, specifically within the dimension of *financial efficiency* (where a written criteria include clear policies for capital investments need to be improved).

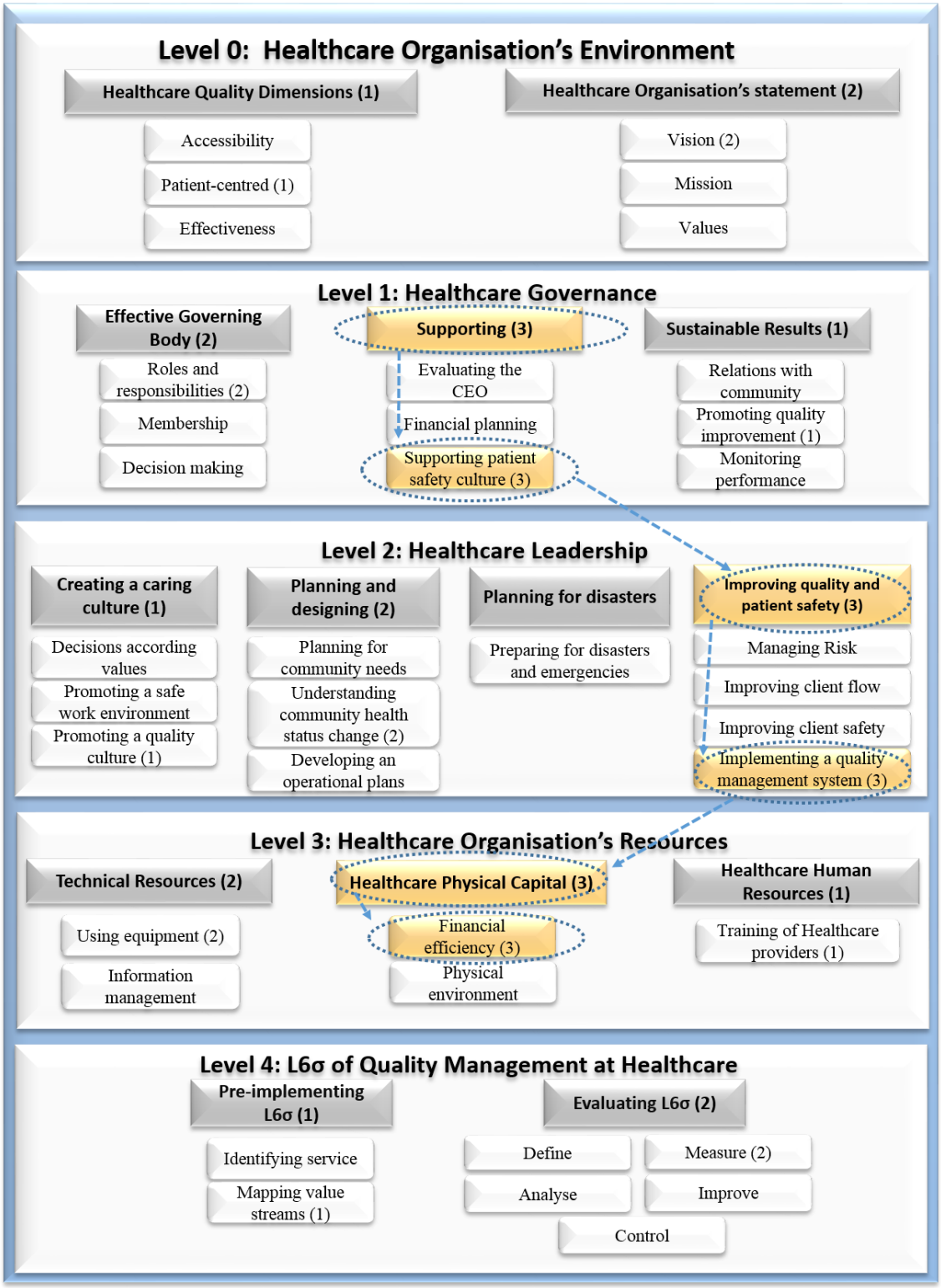


*Figure 5.1 Priority 3 Organisation SQUH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 3 and the audit trail of the rules, Figure 5.11 illustrates the key sub-modules, dimensions, and priority rules across all levels for

improvements to in order to achieve the benchmark in SQUH. Again, for the sake of brevity, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which require action.

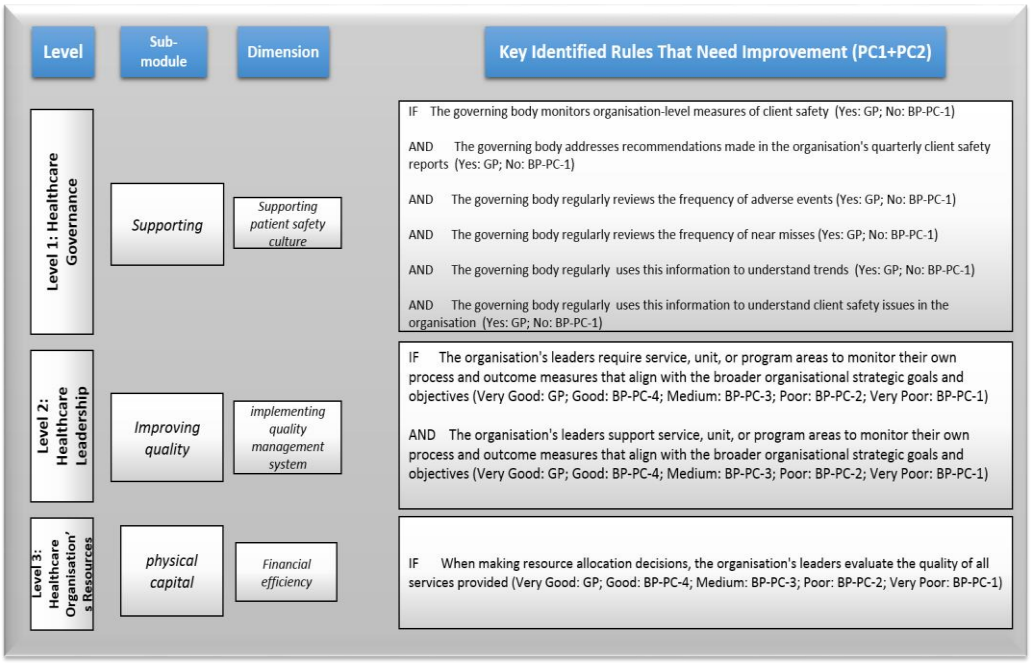


*Figure 5.2 Priority 3 Improvements Actions Identified by KB L6σ-QMHE System for Organisation SQUH*

### *5.4.2 Review of the Organisation SQUH Validation Process*

The validation output of the KB L6σ-QMHE system in SQUH has shown the system's capability in providing a powerful integration between the KB, GAP, and AHP. The KB System has achieved the main research objectives by identifying the prioritised actions for improvements at each level of the organisational structure. It has also shown the audit trail of the KB rules along with the demonstration of key rules at each level.

For Priority 1 *Strategic Decision Levels*, it has been identified that SQUH should focus on the sub-module *healthcare quality dimensions* (*patient-centre* dimension), whereas for Priority 1 *Operational Decision Levels*, the KB System recommends a focus on the *pre-implementing L6σ* sub-module (*mapping value streams* dimension).

## 5.5 Organisation RH: Validation Discussion of KB L6σ-QMHE system

This section will present the results analysis at RH organisation based on the applied validation process as discussed earlier in Section 5.3 for SQUH. The detailed PV calculations are shown in Appendix F. Thus, only the summary results of the validation will be presented for organisation RH for all levels.

### *5.5.1 Summarised KB L6σ-QMHE Output for Organisation RH*

Based on the KB L6σ-QMHE system analysis, Table 5.30 illustrates the summarised results for RH. A total of 964 KB rules were triggered in these modules – the output shows 614 GPs representing the GPs of RH in implementing L6σ-QMHE. However, 350 BPs were identified by the system based on the RH user feedback, which demonstrates the overall organisation performance is about 36.3% lower than the designed benchmark. Yet, the KB L6σ-QMHE system has considered categories PC-1 and PC-2 as the major problematic areas, whereas category PC-3 and above are minor problems. Obviously, it can be seen from Table 5.30 that RH has 13.9% of the BPs as major problematic areas and 22.4% of the BPs as minor problems. The detailed breakdown of the modules' (Level 0–Level 4) BP percentages can be highlighted in ratios (serious: unserious) as 66.1% (28.7:37.4), 37.7% (25.4:12.3), 24.0% (6.3:17.7), 48.2% (9.2:39.0), and 30.4% (8.9:21.5) respectively.

*Table 5.30 Summary of GAP Analysis Results for Royal Hospital*

| Level | Sub-module | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Level 0: Healthcare Organisation's Environment** | Healthcare Organisation's Statement | **52** | **28** | **24** | **5** | **13** | **6** | **0** | **0** |
| | Healthcare Quality Dimensions | **63** | **11** | **52** | **14** | **1** | **11** | **26** | **0** |
| | **Sub-total** | **115** | **39** | **76** | **19** | **14** | **17** | **26** | **0** |
| | **Percentage (%)** | | **33.9** | **66.1** | **28.7** | | **37.4** | | |
| **Level 1: Healthcare Governance** | Effective Governing Body | **93** | **32** | **61** | **21** | **16** | **24** | **0** | **0** |
| | Supporting | **54** | **44** | **10** | **1** | **7** | **2** | **0** | **0** |
| | Sustainable Results | **65** | **56** | **9** | **3** | **6** | **0** | **0** | **0** |
| | **Sub-total** | **212** | **132** | **80** | **25** | **29** | **26** | **0** | **0** |
| | **Percentage (%)** | | **62.3** | **37.7** | **25.4** | | **12.3** | | |
| **Level 2: Healthcare Leadership** | Creating a caring culture | **112** | **72** | **40** | **0** | **0** | **15** | **25** | **0** |
| | Planning and designing | **160** | **137** | **23** | **3** | **6** | **13** | **1** | **0** |
| | Planning for disasters | **44** | **42** | **2** | **0** | **1** | **1** | **0** | **0** |
| | Improving quality | **68** | **41** | **27** | **9** | **5** | **7** | **6** | **0** |
| | **Sub-total** | **384** | **292** | **92** | **12** | **12** | **36** | **32** | **0** |
| | **Percentage (%)** | | **76.0** | **24.0** | **6.3** | | **17.7** | | |
| **Level 3: Healthcare Organisation's Resources** | Human resources | **54** | **11** | **43** | **0** | **10** | **18** | **15** | **0** |
| | Physical Capital | **43** | **30** | **13** | **0** | **1** | **1** | **11** | **0** |
| | Technical resources | **44** | **32** | **12** | **0** | **2** | **1** | **9** | **0** |
| | **Sub-total** | **141** | **73** | **68** | **0** | **13** | **20** | **35** | **0** |
| | **Percentage (%)** | | **51.8** | **48.2** | **9.2** | | **39.0** | | |
| **Level 4: L6σ for QMHE** | Pre-implementing L6σ | **68** | **42** | **26** | **0** | **5** | **21** | **0** | **0** |
| | Evaluating L6σ | **44** | **36** | **8** | **0** | **5** | **3** | **0** | **0** |
| | **Sub-total** | **112** | **78** | **34** | **0** | **10** | **24** | **0** | **0** |
| | **Percentage (%)** | | **69.6** | **30.4** | **8.9** | | **21.5** | | |
| **Grand Total** | | **964** | **614** | **350** | **56** | **78** | **123** | **93** | **0** |
| **Percentage (%)** | | | **63.7** | **36.3** | **13.9** | | **22.4** | | |

As Table 5.31 shows, at *Level 0: Healthcare Organisation's Environment,* the most serious problems were identified in the *healthcare quality dimensions* sub-module and specifically in the *patient-centred* dimension. The second problematic sub-module is the *healthcare organisation's statement,* where the lack of records was triggered in the *values* aspect, and this relates to the governing board working with the organisation's

leaders to update the organisation's values statement. The governing body does not work with the organisation's leaders to seek input from staff to define the organisation's values statement.

Based on the output results of *Level 1: Healthcare Governance,* the most critical part was the *effective governing body* sub-module. The *membership* dimension has proved that RH's new members of the governing body does not receive an orientation before attending their first meeting. The second serious sub-module at *Level 1* is *supporting*. The analysis shows that RH's governing body does not evaluate and oversee the recruitment of the chief executive or senior directors. The least important sub-module at this Level is the *sustainable results.* The analysis, under *monitoring performance* dimension, has shown a gap in preparing an annual report of the achievements of the governing body.

At *Level 2: Healthcare Leadership,* the most serious problems were identified in *creating a caring culture* sub-module and specifically in *promoting a quality culture* dimension. There is a gap in the organisation's leaders being supportive towards mid-level leaders throughout the organisation to develop their capabilities, and to promote a safe and healthy work environment. The second problematic sub-module is the *improving quality***,** where lack of improving client safety has shown to affect the user's output. This has caused a gap in the organisation's policy and process for disclosure of adverse events to clients and families; this also includes support mechanisms for clients who were involved in adverse events. The next important sub-module at this level is *planning and designing.* The analysis has shown a gap in the implementation of the organisation's policies for all key operations.

Moving to *Level 3: Healthcare Organisation's Resources*, the most critical part was the *human resources* sub-module. Some gaps were identified in recruiting and selecting staff in an equitable manner according to individual qualifications and implementing staff retention strategies for leaders. *Physical Capital* is the second serious sub-modules at *Level 3*. Some gaps were identified in *financial efficiency* like; unavailability of a process to move resources to where the leaders in RH need most within and across operational, service or program areas. The next important sub-module at this level is *technical resources.* The analysis shows that RH has some gaps at minor PCs in relation to *using equipment*.

Lastly, at *Level 4: L6σ for Quality Management at Healthcare*, the key sub-module identified by the system was *pre-implementing L6σ* in which a remarkable gap was created in the dimension of *mapping value streams*. In fact, RH's CEO does not track communication with action, precisely by focusing his/ her attention on L6σ issues in direct reports relating to the entire organisation. He/she does not monitor the rolled-up outcomes against plan and taking corrective action. The second serious sub-module at this level is *evaluating L6σ.* Based on the output results of this sub-module, the most critical dimension was *Analyse* where L6σ team does not use Scatter Plots (or any other tool) to analyse the data collected at the measure stage nor analyses Failure Mode and Effect Analysis (FMEA) outcomes.

*Table 5.31 Summary of AHP-PV values for Organisation RH*

| Level | Sub-module | PVs | Dimensions with PVs | | | | |
|---|---|---|---|---|---|---|---|
| **Level 0: Healthcare Org.'s Env.** | Healthcare Organisation's Statement | 0.333 | Vision (0.25) | Mission (0.25) | | Values **(0.50)** | |
| | Healthcare Quality Dimensions | **0.667** | Accessibility (0.163) | Patient-centred (**0.540**) | | Effectiveness (0.297) | |
| **Level 1: Healthcare Governance** | Effective Governing Body | **0.54** | Roles and responsibilities (0.297) | Membership **(0.540)** | | Decision making (0.163) | |
| | Supporting | 0.297 | Evaluating the CEO **(0.50)** | Financial planning (0.25) | | Supporting patient safety culture (0.25) | |
| | Sustainable Results | 0.163 | Relations with community (0.221) | Promoting quality improvement (0.319) | | Monitoring performance **(0.460)** | |
| **Level 2: Healthcare Leadership** | Creating a caring culture | **0.467** | Decisions according values (0.182) | Promoting a safe work environment (0.273) | | Promoting a quality culture **(0.545)** | |
| | Planning and designing | 0.160 | Planning for community needs (**0.540**) | Understanding community health status change (0.163) | | Developing an operational plans (0.297) | |
| | Planning for disasters | 0.095 | Preparing for disasters and emergencies | | | | |
| | Improving quality | 0.277 | Managing Risk (0.10) | Improving client flow (0.199) | Improving client safety (**0.411**) | Implementing a quality management system (0.290) | |
| **Level 3: Healthcare Org.'s Resources** | Human resources | **0.54** | Training of Healthcare providers | | | | |
| | Physical Capital | 0.297 | Financial efficiency (**0.667**) | | | Physical environment (0.333) | |
| | Technical resources | 0.163 | Using equipment (**0.667**) | | | Information management (0.333) | |
| **Level 4: L6σ of QMHE** | Pre-implementing L6σ | **0.667** | Identifying service (0.333) | | | Mapping value streams (**0.667**) | |
| | Evaluating L6σ | 0.333 | Define (0.133) | Measure (0.2) | Analyse **(0.4)** | Improve (0.133) | Control (0.133) |

The KB L6σ-QMHE is embedded within AHP, which also supports RH in prioritising its decision, by facilitating the PV values for each and every part of the system. Table 5.31 illustrates the PV values for each module (Level 0–Level 4), which

are used to formulate the developed KB L6σ-QMHE framework with the critical areas highlighted.

*5.5.1.1 Priority 1 Improvements for Organisation RH*

The developed KB L6σ-QMHE framework shown in Figure 5.13 illustrates a Priority 1 visual improvement roadmap for RH prioritised by the KB-AHP-GAP System. Starting from the strategic levels, the AHP aspect of the KB System has the highest priority (1) at *Level 0: Healthcare Organisation's Environment* that RH should improve on. Within this module, the sub-module *healthcare quality dimensions* has been identified as the key where the *patient-centred* dimension plays a major role.

Thereafter, at *Level 1: Healthcare Governance*, the KB System has identified the sub-module *effective governing body* as Priority 1, specifically within the dimension of *membership*, (by ensuring that new members of the governing body receive an orientation before attending their first meeting). Then, at *Level 2: Healthcare Leadership*, the KB System recommends the need to start improvements with the *creating a caring culture* sub-module, in which *promoting a quality culture* dimension has identified the unavailability of the organisation's policy and process for disclosure of adverse events to clients and families.

Next, at *Level 3: Healthcare Organisation's Resources*, the KB System has identified the sub-module *human resources* as Priority 1, where RH should give more attention for recruiting and selecting staff in an equitable manner according to individual qualifications and implementing staff retention strategies for leaders. Finally, at *Level 4: L6σ for Quality Management at Healthcare*, the KB System recommends the need to start improvements with the *pre-implementing L6σ* sub-module, in which the *mapping value streams* dimension has identified the lack of knowledge in tracking communication with

action, therefore there is need to focus attention on L6σ issues from direct reports in relation to the entire organisation.

One of the important aspects of this developed KB System is to have a complete audit trail of the KB rules that have identified prioritised actions for improvement by the AHP and GAP methodologies in order to achieve the benchmark. Hence, Figure 5.12 shows the KB System's prioritised audit trail (Priority 1) in detail, which can be used to assist with decision making, and to develop an action plan for RH across the whole organisation (Level 0–Level 4) in order to achieve the benchmark.

In this case, it is recommended to start with the *patient-centred* dimension at Level 0, followed by the *membership* dimension at Level 1, followed by the *promoting a quality culture* dimension at Level 2, followed by the *training healthcare providers* dimension at Level 3, and completed by the *mapping value streams* dimension at Level 4. It can be treated in a step-by-step manner as shown and described above, bearing in mind the immediate actions to be taken for the most serious problems which represent 13.9% of the BPs.

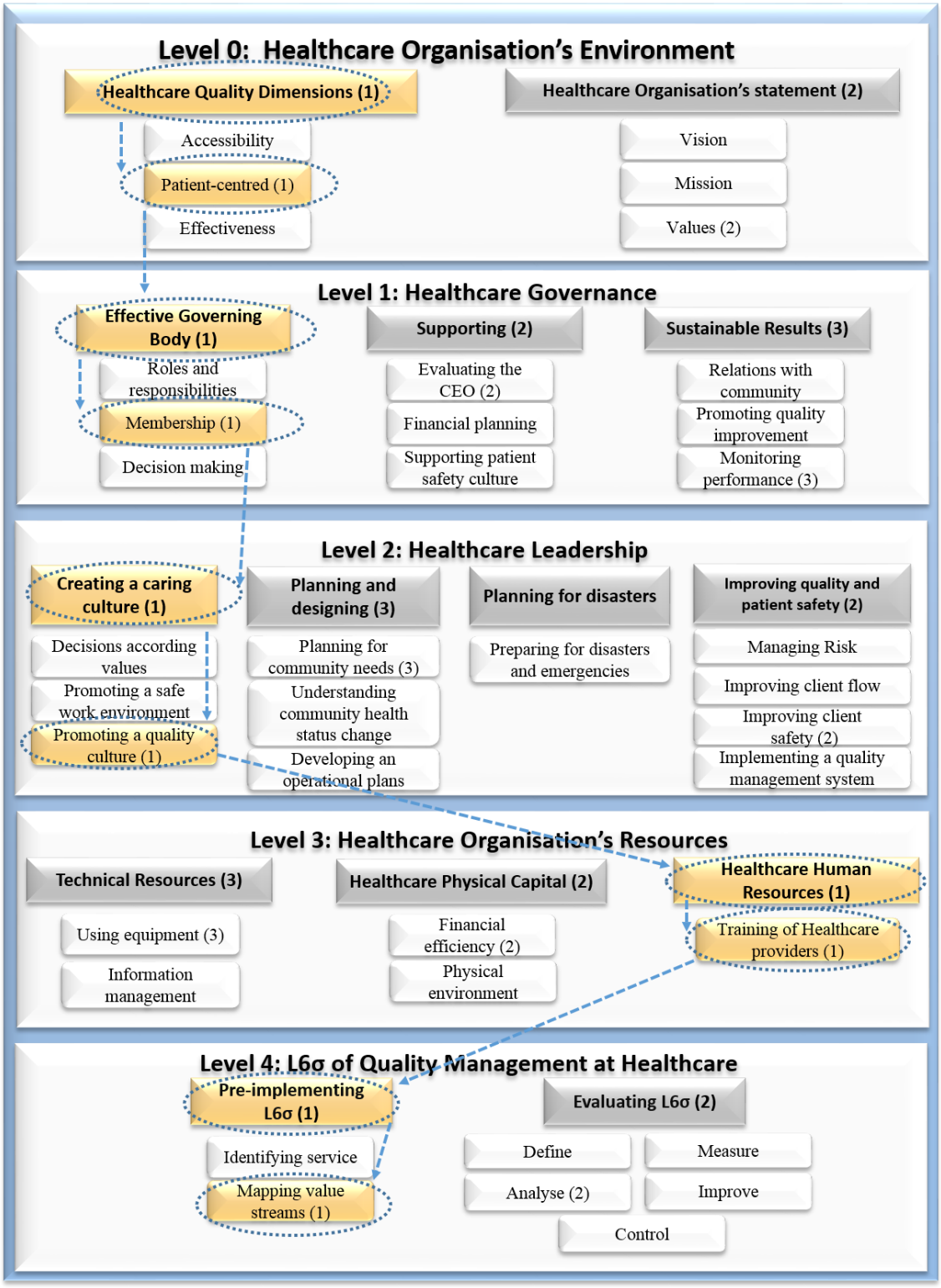


*Figure 5.3 Priority 1 Organisation RH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 1 and the audit trail of the rules, Figure 5.13 illustrates the key sub-modules, dimensions, and priority rules across all levels for

improvements in order to achieve the benchmark in RH. For the sake of briefness, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which requires action.

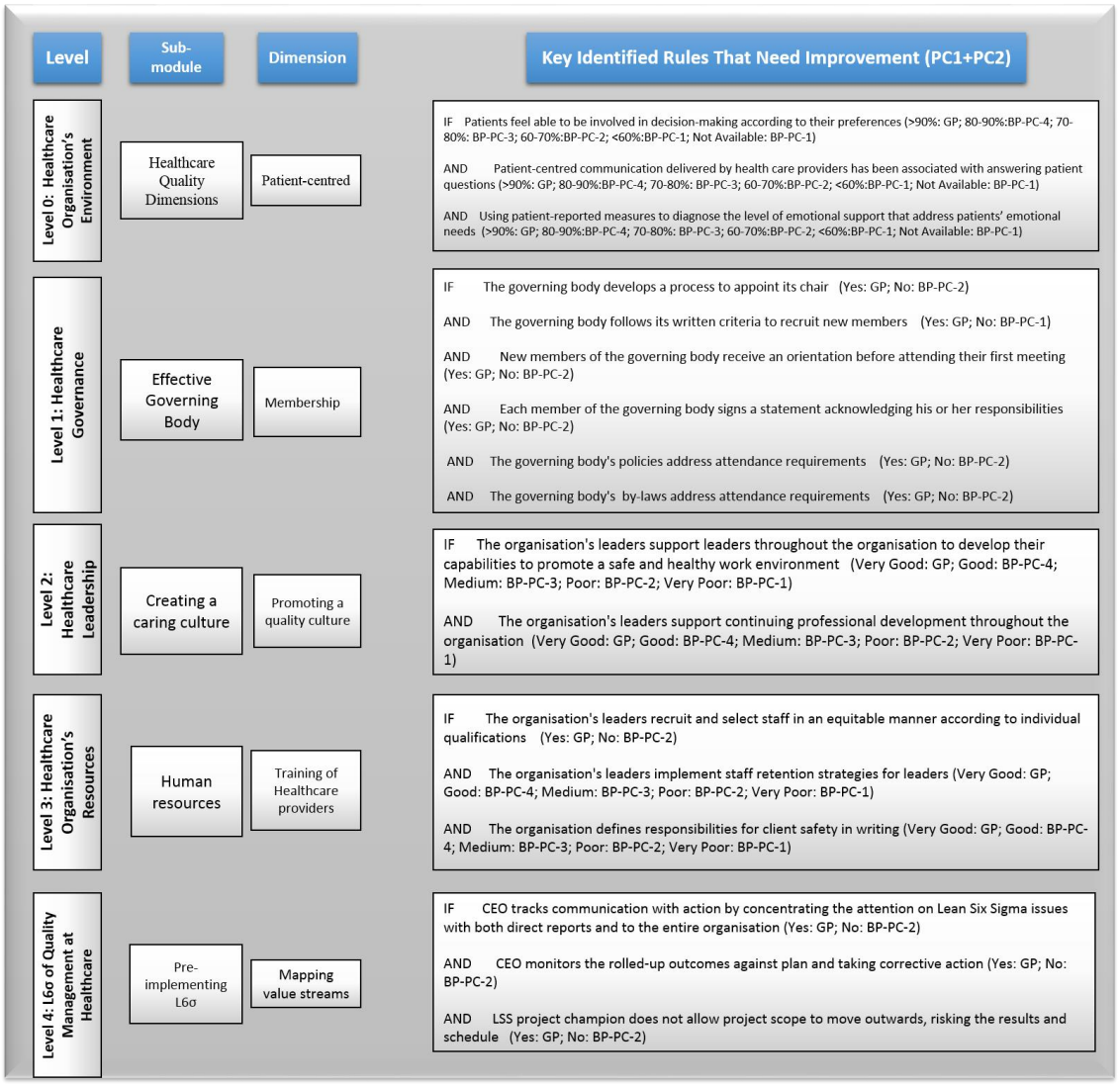


*Figure 5.4 Priority 1 Improvements Actions Identified by KB L6σ-QMHE System for Organisation RH*

The above figure of the identified key rules shows that RH has to involve patients and their families in their decision-making process in accordance to the preferences of users as well as use patient-reported measures to diagnose the level of emotional support that can address patients' emotional needs. Besides not maintaining a system of a governing body that appoints a chair, also highlights that new members of the governing

body do not receive an orientation before attending their first meeting. Similarly, RH should focus on recruiting and selecting staff in an equitable manner according to individual qualifications and implementing staff retention strategies for leaders. Finally, it has to identify ways to improve mapping value streams that affect L6σ projects dramatically.

*5.5.1.2 Priority 2 Improvements for Organisation RH*

The developed KB L6σ-QMHE framework shown in Figure 5.14 illustrates a Priority 2 visual improvement roadmap for RH prioritised by the KB-AHP-GAP System. Starting from the strategic levels, the AHP aspect of the KB System has the second priority of *Level 0: Healthcare Organisation's Environment* that RH should improve on. Within this module, the sub-module *healthcare organisation's statement*, is considered to be the Priority 2, where lack of records has been triggered in the *values* aspect with regards to the governing body working with the organisation's leaders to update the organisation's values statement.

Thereafter, at *Level 1: Healthcare Governance*, the KB System has identified the sub-module *effective governing body* as Priority 2, specifically within the dimension of *membership*. Then, at *Level 2: Healthcare Leadership*, the second problematic sub-module is *improving quality*, where lack of *improving client safety* has shown as part of the user's output. This has caused a gap in the organisation's policy and process for disclosure of adverse events to clients and families, includes support mechanisms for clients who have been involved in adverse events.

Next, at *Level 3: Healthcare Organisation's Resources,* the KB System has identified the sub-module *physical Capital* as Priority 2, specifically within the dimension of *financial efficiency* because of the unavailability of a process to move resources to where the RH's leaders need it most within and across operational, service or program

areas. Finally, at *Level 4: L6σ for Quality Management at Healthcare*, the second KB System recommendation is the *evaluation of L6σ* sub-module, in which the *Analyse* dimension has identified lack of using Scatter Plots (or any other tool) to analyse the data collected in measure stage and lack of using FMEA outcomes in analyses.

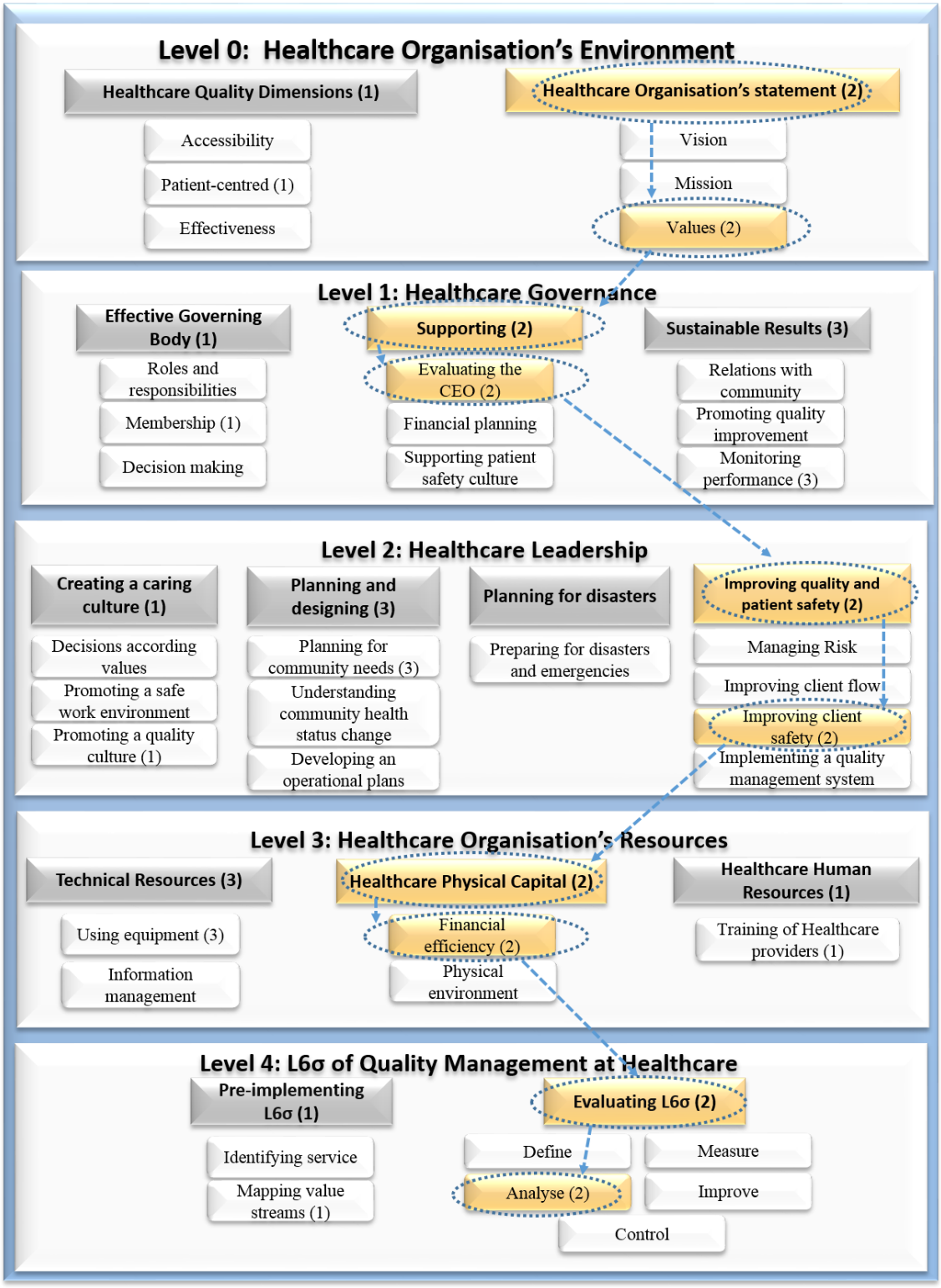


*Figure 5.5 Priority 2 Organisation RH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 2 and the audit trail of the rules, Figure 5.15 illustrates the key sub-modules, dimensions, and priority rules across all levels for

improvements to achieve the benchmark in RH. Again, for the sake of brevity, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which need action.

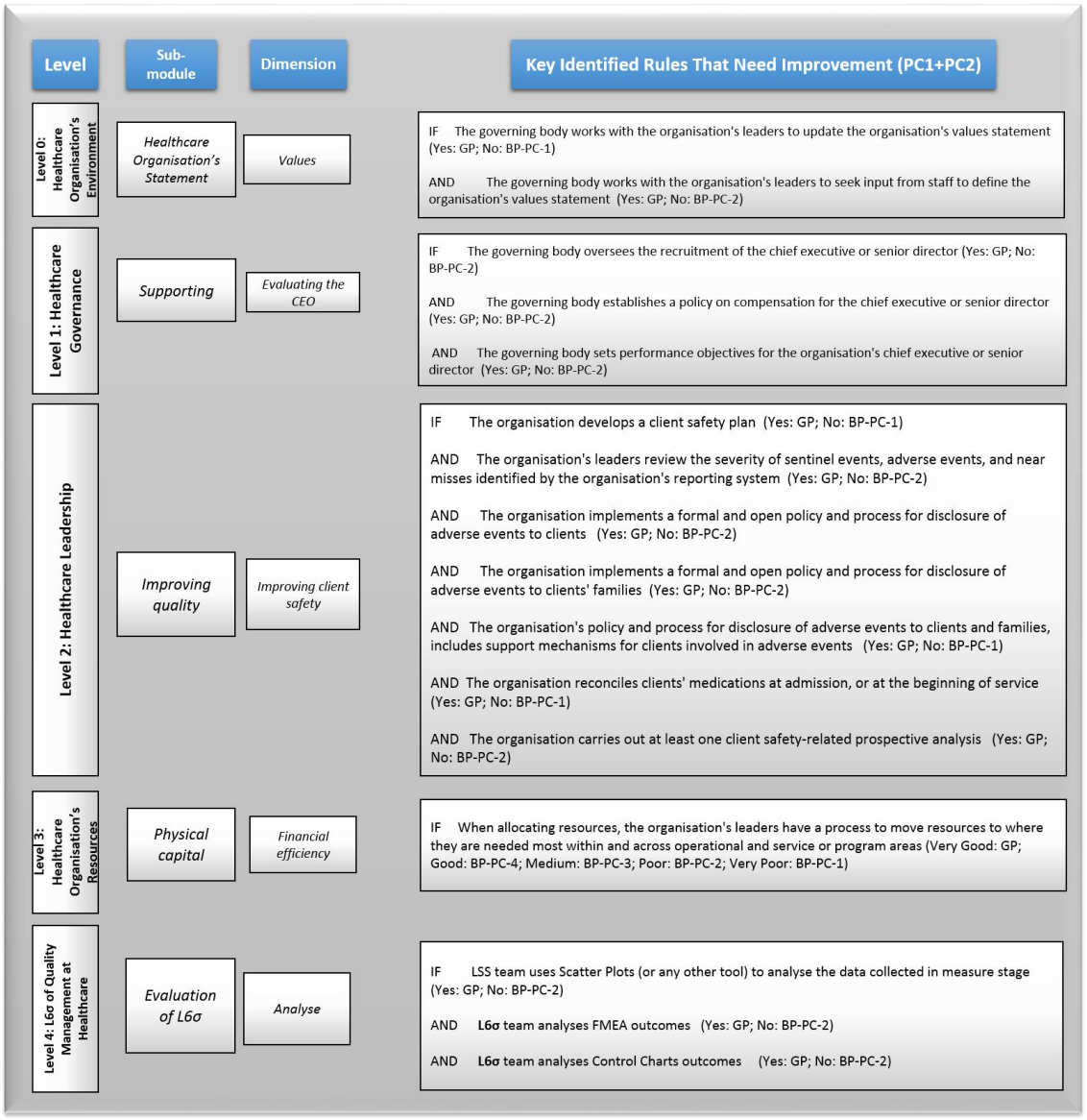


*Figure 5.6 Priority 2 Improvements Actions Identified by KB L6σ-QMHE System for Organisation RH*

It can be seen in the figure above that the KB System has identified some critical issue for Priority 2 improvements at all levels. Some of these dimensions have only 1 or 2 BPs. However, there were still some KB rules that have been detected (at minor levels from PC3 to PC4) by the AHP, and this will not cause any problem in the short term.

Nevertheless, neglecting the same may cascade to future leadership implications. Therefore, it is recommended that these gaps be addressed in order to achieve the L6σ-QMHE benchmark.

*5.5.1.3 Priority 3 Improvements for Organisation RH*

The developed KB L6σ-QMHE framework shown in Figure 5.16 illustrates a Priority 3 visual improvement roadmap for RH prioritised by the KB-AHP-GAP System. At *Level 1: Healthcare Governance,* the KB System has identified the sub-module *sustainable results* as Priority 3, specifically within the dimension of *monitoring performance*. Then, at *Level 2: Healthcare Leadership,* the third problematic sub-module is the *planning and designing***,** where it shows a gap in *planning for community needs* in terms of implementing organisation's policies for all key operations.

Finally, at *Level 3: Healthcare Organisation's Resources,* the KB System has identified the sub-module *technical resources* as Priority 3, specifically within the dimension of *using equipment*.

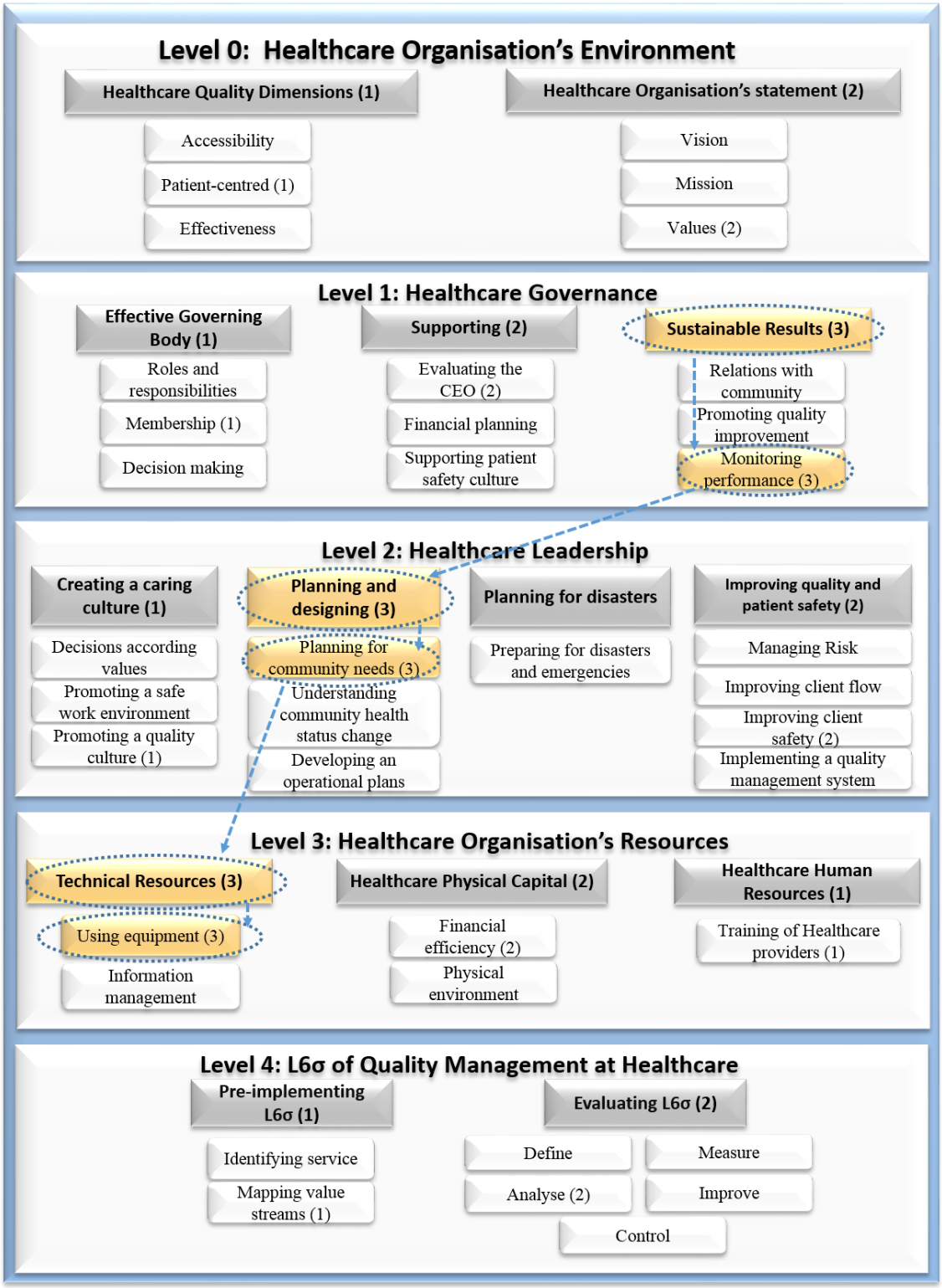


*Figure 5.7 Priority 3 Organisation RH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 3 and the audit trail of the rules, Figure 5.17 illustrates the key sub-modules, dimensions, and priority rules across all levels for

improvements to in order to achieve the benchmark in RH. Again, for the sake of brevity, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which need action.

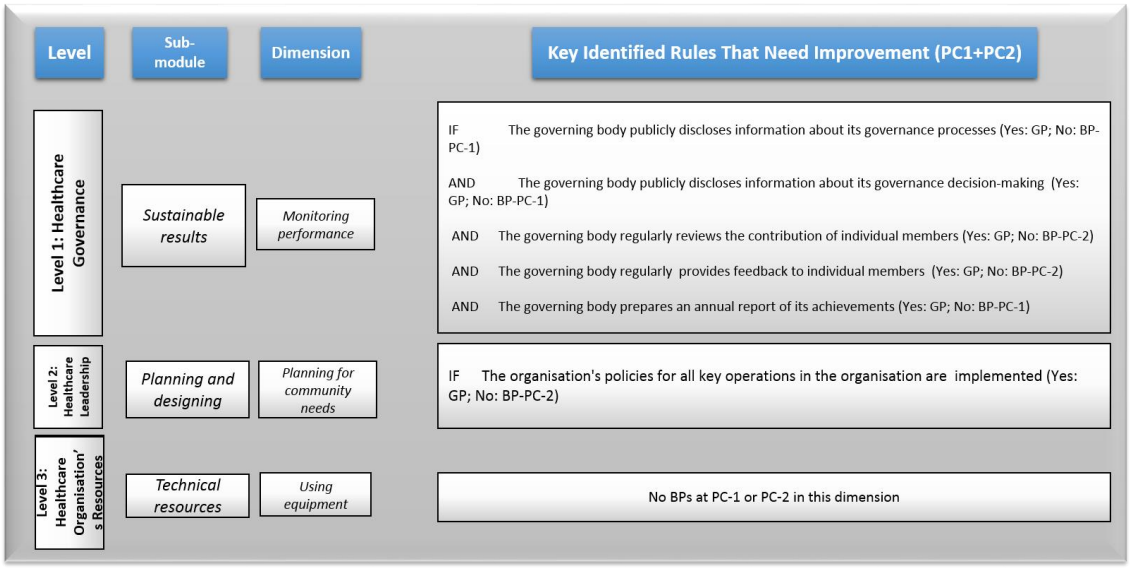


*Figure 5.8 Priority 3 Improvements Actions Identified by KB L6σ-QMHE System for Organisation RH*

### *5.5.2 Review of the Organisation RH Validation Process*

The validation output of the KB L6σ-QMHE system at RH has shown the system's capability in providing a powerful integration between the KB, GAP, and AHP. The KB System has achieved the main research objectives by identifying the prioritised actions for improvements at each level of the organisational structure. It has, also, shown that the audit trail of the KB rules along with the demonstration of key rules at each Level.

For Priority 1 *Strategic Decision Levels*, it has been identified that RH should focus on the sub-module *healthcare quality dimensions* (*patient-centred* dimension), whereas for Priority 1 *Operational Decision Levels*, the KB System has recommended a focus on the *pre-implementing L6σ* sub-module (*mapping value streams* dimension).

## 5.6 Organisation KH: Validation Discussion of KB L6σ-QMHE system

This section will present the results analysis at KH organisation based on the applied validation process as discussed earlier in Section 5.3 for organisation SQUH. The detailed PV calculations are shown in Appendix G. Thus, only the summary results of the validation will be presented for organisation RH for Levels 0-3 only.

### *5.6.1 Summarised KB L6σ-QMHE Output for Organisation KH*

Based on the KB L6σ-QMHE system analysis, Table 5.32 illustrates the summarised results for KH. 852 KB rules were triggered in these modules – the output shows 521 GPs representing the GPs of KH in implementing L6σ-QMHE. However, 331 BPs were identified by the system based on the KH user feedback, which demonstrates the overall organisation performance is about 38.8% lower than the designed benchmark. Similarly, the KB L6σ-QMHE system has considered categories PC-1 and PC-2 as the major problematic areas, whereas category PC-3 and above are minor problems. Obviously, it can be seen from Table 5.32 that KH has 13.7% of the BPs as major problematic areas and 25.1% of the BPs as minor problems. The detailed breakdown of the modules' (Level 0–Level 3) BP percentages can be highlighted in ratios (serious: unserious) as 54.8% (26.1:28.7), 31.1% (22.6:8.5), 31.8% (6.8:25.0), and 56.7% (9.2:47.5) respectively.

*Table 5.32 Summary of GAP Analysis Results for KH*

| Level | Sub-module | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Level 0: Healthcare Organisation's Environment** | Healthcare Organisation's Statement | **52** | **31** | **21** | **7** | **10** | **4** | **0** | **0** |
| | Healthcare Quality Dimensions | **63** | **21** | **42** | **8** | **5** | **11** | **18** | **0** |
| | **Sub-total** | **115** | **52** | **63** | **15** | **15** | **15** | **18** | **0** |
| | **Percentage (%)** | | **45.2** | **54.8** | **26.1** | | **28.7** | | |
| **Level 1: Governance Leadership** | Effective Governing Body | **93** | **61** | **32** | **8** | **13** | **11** | **0** | **0** |
| | Supporting | **54** | **36** | **18** | **5** | **12** | **1** | **0** | **0** |
| | Sustainable Results | **65** | **49** | **16** | **3** | **7** | **3** | **3** | **0** |
| | **Sub-total** | **212** | **146** | **66** | **16** | **32** | **15** | **3** | **0** |
| | **Percentage (%)** | | **68.9** | **31.1** | **22.6** | | **8.5** | | |
| **Level 2: Healthcare Leadership** | Creating a caring culture | **112** | **50** | **62** | **2** | **3** | **15** | **42** | **0** |
| | Planning and designing | **160** | **147** | **13** | **1** | **1** | **10** | **1** | **0** |
| | Planning for disasters | **44** | **38** | **6** | **0** | **2** | **4** | **0** | **0** |
| | Improving quality | **68** | **27** | **41** | **6** | **11** | **19** | **5** | **0** |
| | **Sub-total** | **384** | **262** | **122** | **9** | **17** | **48** | **48** | **0** |
| | **Percentage (%)** | | **68.2** | **31.8** | **6.8** | | **25.0** | | |
| **Level 3: Healthcare Organisation's Resources** | Human resources | **54** | **1** | **53** | **0** | **8** | **36** | **9** | **0** |
| | Physical Capital | **43** | **28** | **15** | **0** | **3** | **3** | **9** | **0** |
| | Technical resources | **44** | **32** | **12** | **0** | **2** | **1** | **9** | **0** |
| | **Sub-total** | **141** | **61** | **80** | **0** | **13** | **40** | **27** | **0** |
| | **Percentage (%)** | | **43.3** | **56.7** | **9.2** | | **47.5** | | |
| **Grand Total** | | **852** | **521** | **331** | **40** | **77** | **118** | **96** | **0** |
| **Percentage (%)** | | | **61.2** | **38.8** | **13.7** | | **25.1** | | |

As Table, 5.32 shows, at *Level 0: Healthcare Organisation's Environment,* the most serious problems were identified in the *healthcare quality dimensions* sub-module and specifically in the *patient-centred* dimension. The second problematic sub-module is the *healthcare organisation's statement,* where the lack of records has been triggered in the *values* aspect, and this is in relation to regular consultations of the governing body and the government to confirm the appropriateness of the organisation's mandate and core services.

Based on the output results of *Level 1: Healthcare Governance,* the most critical part was the *effective governing body* sub-module. The *membership* dimension has proved that members of the governing body in KH does not receive ongoing education to help them fulfil the requirements of being a member of the governing body. The second serious sub-module at *Level 1* is *supporting*. The analysis shows that KH's governing body, in terms of *financial planning*, does not review the organisations' financial performance in relation to risk. The least important sub-module at this Level is the *sustainable results.* The analysis has shown a gap in encouraging feedback from the community about the organisation and its services.

At *Level 2: Healthcare Leadership,* the most serious problems were identified in the *creating a caring culture* sub-module and specifically in the *promoting a quality culture* dimension. There is a gap in providing support for quality of work life improvement activities by the leaders of the organisation. The second problematic sub-module is the *improving quality***,** where the lack of *managing risk* has shown as part of the user's output. This has caused a gap in the evaluation of the quality for contracted services as part of the integrated risk management approach. The next important sub-module at this level is *planning and designing.* The analysis has shown a gap in the implementation of the organisation's policies for all systems.

Finally, at *Level 3: Healthcare Organisation's Resources*, the most critical part was the *human resources* sub-module. Some gaps were identified in recruiting and selecting staff in an equitable manner according to individual qualifications and implementing staff retention strategies for leaders. *Physical Capital* is the second serious sub-modules at *Level 3*. Some gaps were identified in *financial efficiency* like; unfollowing a set of criteria to guide resources allocation decisions. The next important

sub-module at this level is *technical resources.* The analysis shows that KH has some gaps at minor PCs in *using equipment*.

*Table 5.33 Summary of AHP-PV values for Organisation KH*

| Level | Sub-module | PVs | Dimensions with PVs | | | |
|---|---|---|---|---|---|---|
| **Level 0: Healthcare Org.'s Environment** | Healthcare Organisation's Statement | 0.333 | Vision (0.163) | Mission (0.297) | | Values (**0.540**) |
| | Healthcare Quality Dimensions | **0.667** | Accessibility (0.167) | Patient-centred **(0.50)** | | Effectiveness (0.333) |
| **Level 1: Healthcare Governance** | Effective Governing Body | **0.540** | Roles and responsibilities (0.297) | Membership **(0.540)** | | Decision-making (0.163) |
| | Supporting | 0.297 | Evaluating the CEO (0.273) | Financial planning **(0.545)** | | Supporting patient safety culture (0.182) |
| | Sustainable Results | 0.163 | Relations with community (**0.545**) | Promoting quality improvement (0.273) | | Monitoring performance (0.182) |
| **Level 2: Healthcare Leadership** | Creating a caring culture | **0.467** | Decisions according values (0.182) | Promoting a safe work environment (0.273) | | Promoting a quality culture (**0.545**) |
| | Planning and designing | 0.16 | Planning for community needs (**0.545**) | Understanding community health status change (0.182) | | Developing an operational plans (0.273) |
| | Planning for disasters | 0.095 | Preparing for disasters and emergencies | | | |
| | Improving quality | 0.277 | Managing Risk (**0.478**) | Improving client flow (0.134) | Improving client safety (0.207) | Implementing a QM system (0.181) |
| **Level 3: Healthcare Org.'s Resources** | Human resources | **0.5** | Training of Healthcare providers | | | |
| | Physical Capital | 0.333 | Financial efficiency (**0.667**) | | | Physical environment (0.333) |
| | Technical resources | 0.167 | Using equipment (**0.667**) | | | Information management (0.333) |

The KB L6σ-QMHE is embedded within AHP, which also supports KH in prioritising its decision, by facilitating the PV values for each and every part of the system. Table 5.32 illustrates the PV values for each module (Level 0–Level 3), which

are used to formulate the developed KB L6σ-QMHE framework with the critical areas are highlighted.

*5.6.1.1 Priority 1 Improvements for Organisation KH*

The developed KB L6σ-QMHE framework shown in Figure 5.18 illustrates a Priority 1 visual improvement roadmap for KH prioritised by the KB-AHP-GAP System. Starting from the strategic levels, the AHP aspect of the KB System has the highest priority (1) of *Level 0: Healthcare Organisation's Environment* that KH should improve on. Within this module, the sub-module *healthcare quality dimensions* has been identified as the key where the *patient-centred* dimension plays the major role.

Thereafter, at *Level 1: Healthcare Governance*, the KB System has identified the sub-module *effective governing body* as Priority 1, specifically within the dimension of *membership*, (by ensuring that new members of the governing body in KH receive ongoing education to help them fulfil the requirements of being a member of the governing body). Then, at *Level 2: Healthcare Leadership*, the KB System recommends the need to start improvements with the *creating a caring culture* sub-module, in which *promoting a quality culture* dimension has identified some gaps that relates to a healthy work environment as a strategic priority and providing support for quality of work life improvement activities by the leaders of the organisation.

Next, *Level 3: Healthcare Organisation's Resources*, the KB System has identified the sub-module *human resources* as Priority 1, where KH should give more attention for recruiting and selecting staff in an equitable manner according to individual qualifications and implementing staff retention strategies for leaders, and use a staffing process that is evidence based.

One of the important aspects of this developed KB System is to have a complete audit trail of the KB rules that have identified prioritised actions for improvement by the

AHP and GAP methodologies in order to achieve the benchmark. Hence, Figure 5.19 shows the KB System's prioritised audit trail (Priority 1) in detail, which can be used to assist with decision making, and to develop an action plan for KH across the whole organisation (Level 0–Level 3), in order to achieve the benchmark.

In this case, it is recommended to start with the *patient-centred* dimension at Level 0, followed by the *membership* dimension at Level 1, followed by the *promoting a quality culture* dimension at Level 2, and completed by the *training healthcare providers* dimension at Level 3. It can be treated in a step-by-step manner as shown and described above, bearing in mind the immediate actions to be taken for the most serious problems which represent 13.7% of the BPs.

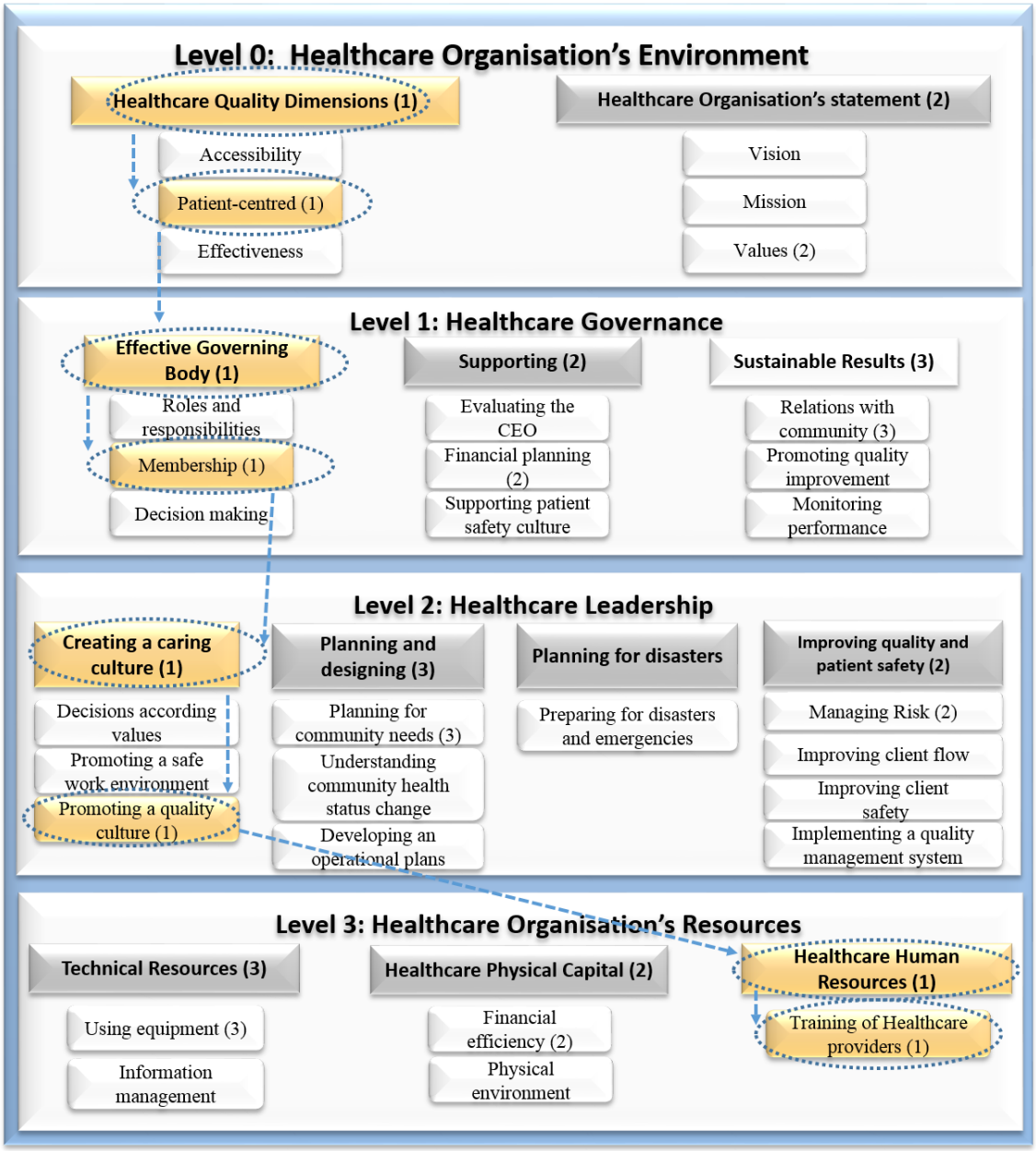


*Figure 5.9 Priority 1 Organisation KH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 1 and the audit trail of the rules, Figure 5.19 illustrates the key sub-modules, dimensions, and priority rules across all levels for improvements in order to achieve the benchmark in KH. For the sake of briefness, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which requires action.

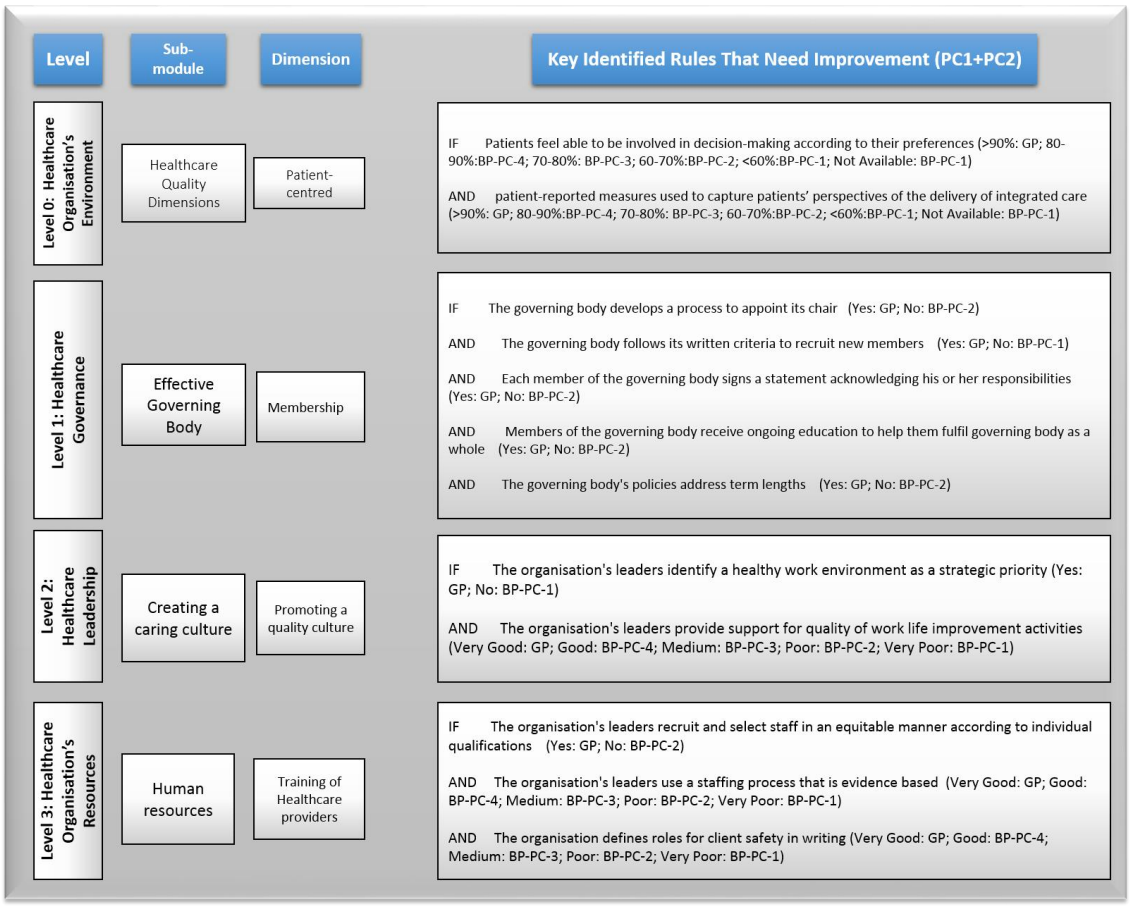


*Figure 5.19 Priority 1 Improvements Actions Identified by KB L6σ-QMHE System for Organisation KH*

The above figure of the identified key rules shows that KH has to use measures that enable healthcare providers to capture patients' perspectives of the delivery of integrated services. Patients should also be involved in the decision-making process, and in accordance to their preferences. In addition, KH is not maintaining a system of governing body that allows for the appointment of its chair, similarly new members of the governing body do not receive ongoing education to help them fulfil governing body as a whole. Furthermore, KH should focus on recruiting and selecting staff in an equitable manner according to individual qualifications and implementing staff retention strategies for leaders, and use a staffing process that is evidence based.

*5.6.1.2 Priority 2 Improvements for Organisation KH*

The developed KB L6σ-QMHE framework shown in Figure 5.20 illustrates a Priority 2 visual improvement roadmap for KH prioritised by the KB-AHP-GAP System. Starting from the strategic levels, the AHP aspect of the KB System has the second priority of *Level 0: Healthcare Organisation's Environment* that KH should improve on. Within this module, the sub-module *healthcare organisation's statement*, is considered to be the Priority 2, where lack of records has been triggered in the *values* aspect, and this relates to regular consultations of the governing body with the government to confirm the appropriateness of the organisation's mandate and core services.

Therefore at *Level 1: Healthcare Governance*, the KB System has identified the sub-module *supporting* as Priority 2, specifically within the dimension of *financial planning*. Examples of gaps can be seen in terms of not reviewing the organisation's financial performance in relation to risk. Then, at *Level 2: Healthcare Leadership,* the second problematic sub-module is the *improving quality***,** where the lack of *managing risk* has shown as part of the user's output. This has caused a gap in evaluation of the quality for contracted services as part of the integrated risk management approach.

Finally, at *Level 3: Healthcare Organisation's Resources*, the KB System has identified the sub-module *physical Capital* as Priority 2, specifically within the dimension of *financial efficiency* because of the weakness in recruiting and selecting staff in an equitable manner according to individual qualifications and implementing staff retention strategies for leaders.

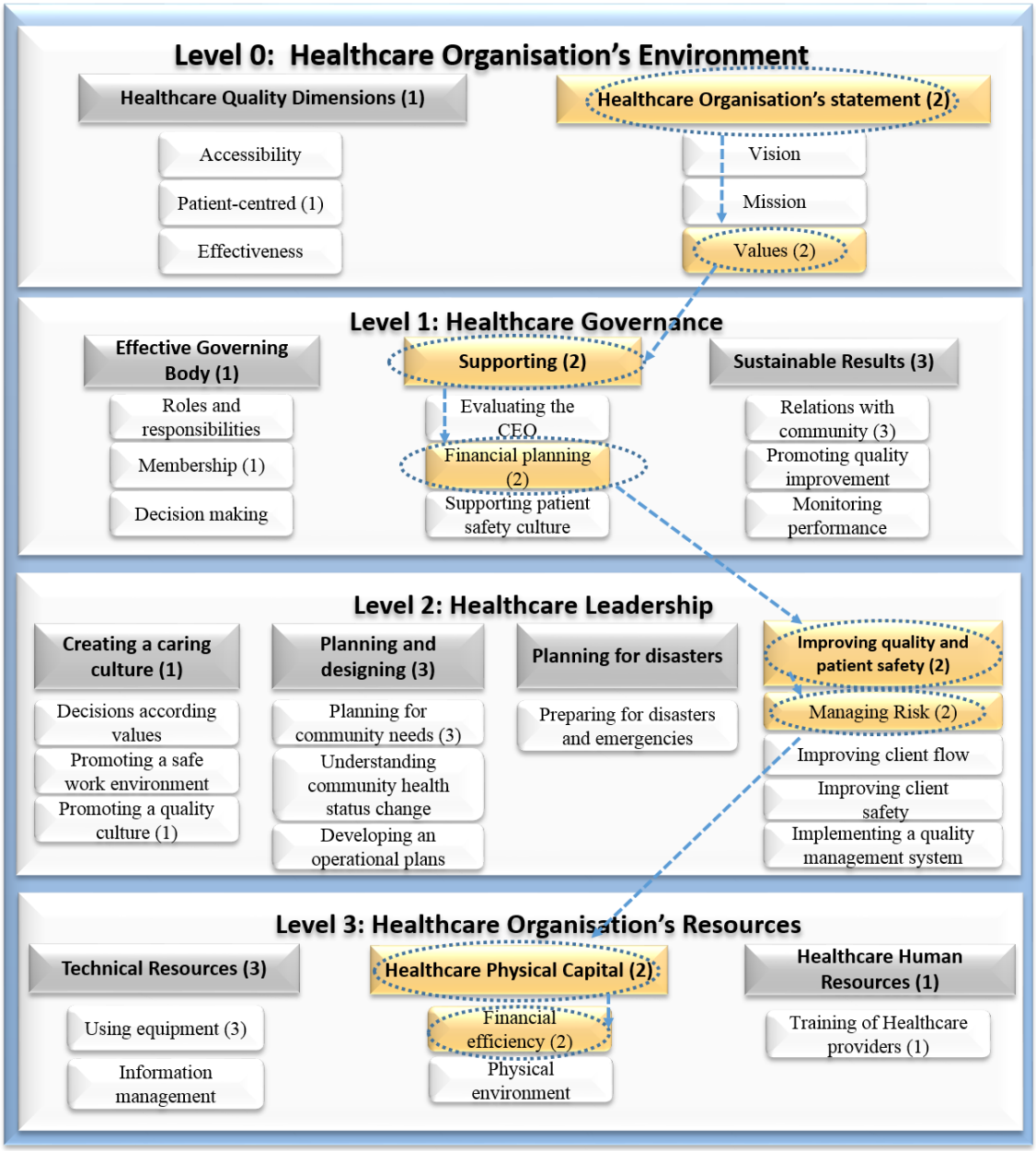


*Figure 5.10 Priority 2 Organisation KH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 2 and the audit trail of the rules, Figure 5.21 illustrates the key sub-modules, dimensions, and priority rules across all levels for improvements in order to achieve the benchmark in KH. Again, for the sake of brevity, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which requires action.

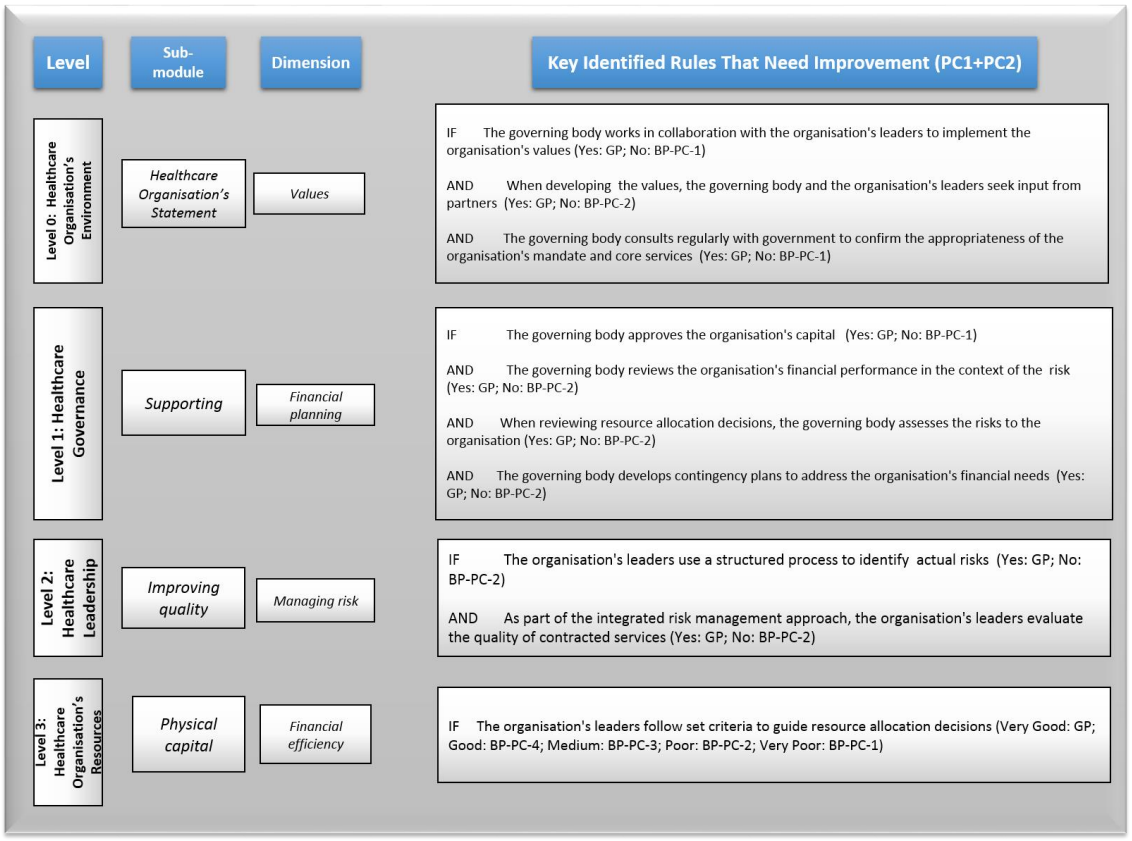


*Figure 5.11 Priority 2 Improvements Actions Identified by KB L6σ-QMHE System for Organisation KH*

It can be seen in the figure above that the KB System has identified some critical issue for Priority 2 improvements at all levels. Some of these dimensions have only 1 or 2 BPs. However, there were still some KB rules that have been detected (at minor levels from PC3 to PC4) by AHP and this will not cause any problem in the short term. Nevertheless, neglecting the same may cascade to future leadership implications. Therefore, it is recommended that these gaps be addressed in order to achieve the L6σ-QMHE benchmark.

### *5.6.1.3 Priority 3 Improvements for Organisation KH*

The developed KB L6σ-QMHE framework shown in Figure 5.22 illustrates a Priority 3 visual improvement roadmap for KH prioritised by the KB-AHP-GAP System. At *Level 1: Healthcare Governance*, the KB System has identified the sub-module

*sustainable results* as Priority 3, specifically within the dimension of *relations with community*. The output shows a weakness in encouraging feedback from the community about the organisation and its services. Then, at *Level 2: Healthcare Leadership*, the third problematic sub-module is the *planning and designing*, where it shows a gap in *planning for community needs*. The analysis has shown a gap in the implementation of organisation's policies for all systems.

Finally, at *Level 3: Healthcare Organisation's Resources*, the KB System has identified the sub-module *technical resources* as Priority 3, specifically within the dimension of *using equipment*.

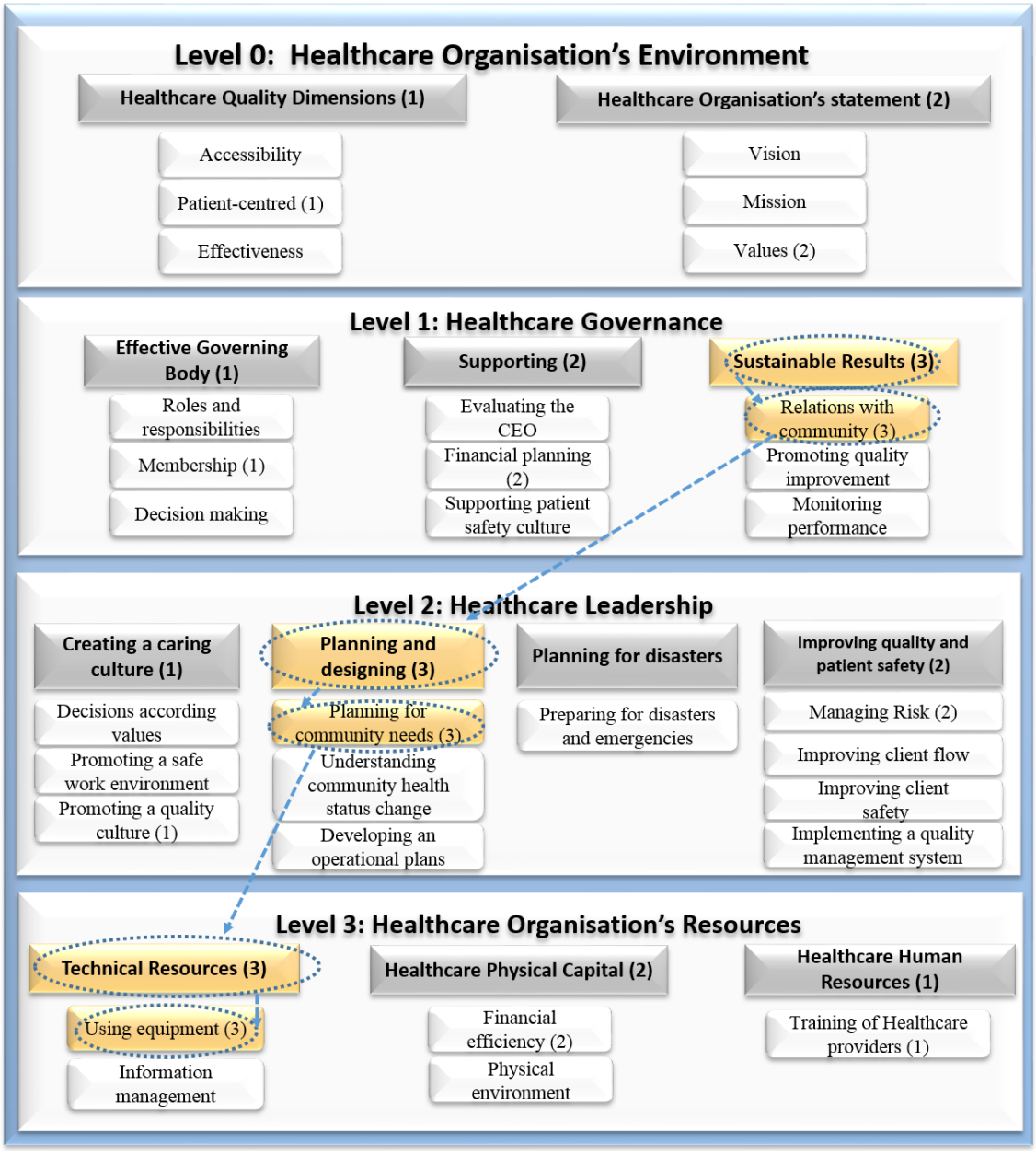


*Figure 5.12 Priority 3 Organisation KH: Developed L6σ-QMHE Framework*

In terms of the KB System, AHP Priority 3 and the audit trail of the rules, Figure 5.23 illustrates the key sub-modules, dimensions, and priority rules across all levels for improvements in order to achieve the benchmark in KH. Again, for the sake of brevity, only PC-1 and PC-2 are shown, however, the KB System shows an audit trail for all of the rule-based PCs identified and which require action.

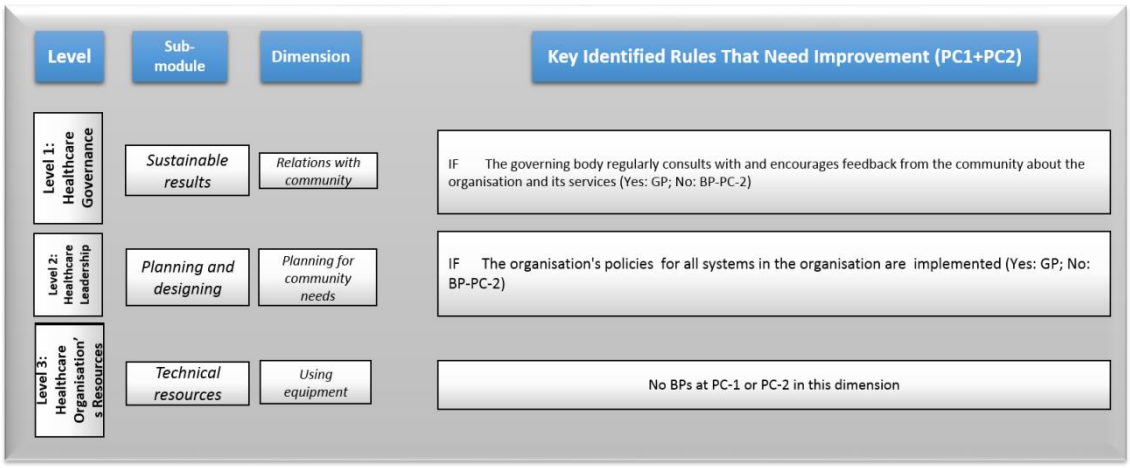


*Figure 5.13 Priority 3 Improvements Actions Identified by KB L6σ-QMHE System for Organisation KH*

### *5.6.2 Review of the Organisation KH Validation Process*

The validation output of the KB L6σ-QMHE system at KH has shown the system's capability in providing a powerful integration between the KB, GAP, and AHP. The KB System has achieved the main research objectives by identifying the prioritised actions for improvements in each level of the organisation structure. It has also shown the audit trail of the KB rules along with the demonstration of key rules at each level.

For Priority 1 *Strategic Decision Levels*, it has been identified that KH should focus on the sub-module *healthcare quality dimensions* (*patient-centred* dimension), whereas for Priority 1 *Operational Decision Levels*, the KB System has recommended concentration on the *human resources* sub-module (*training of healthcare providers* dimension).

## 5.7 Summary

This chapter has provided a discussion of the results in relation to the validation process in three healthcare organisations. The logic behind applying the validation process is to show the capability of the KB L6σ-QMHE system in optimising the decision-making process. The GAP and AHP analysis results were examined to identify

the priorities between modules and sub-modules to achieve the benchmark performance improvements. Also, the process can confirm the capability of the developed system in giving valid decisions in a current situation.

The validation process has shown how the KB System helps to capture data related to the organisation's performance. It has also shown how the rules are embedded in each module to establish relationships, and convert this data into information. Furthermore, the system proves to be capable in assessing and comparing the organisation's level of performance with the L6σ-QMHE benchmark, and proposing prioritised recommendations (in both strategic and operational levels) of current issues. The system has shown the ability to demonstrate the audit trail of the KB rules, key sub-modules, key dimensions, and the key priority rules across the framework levels.

The developed KB L6σ-QMHE system is validated through three hospitals in Oman. Out of the three hospitals, SQUH and RH have participated in validating *Level 0* to *Level 4*, whereas KH has been involved in validating *Level 0 to Level 3 of* the system. In the validating *Level 0* to *Level 4*, the KB System has recorded that SQUH practices 14.6% of serious problems out of all the issues (problem categories) identified. In RH, the figure was less, where it accounts for 13.9% of the total BPs. On the other hand, the validation of *Level 0 to Level 3* revealed that the most serious problematic areas recorded in KH represent 13.7% of the total problems identified.

Based on SQUH's validation process, the KB L6σ-QMHE system has clearly shown the **Priority 1**, at *Level 0*, is to focus on the *patient-centred* dimension in the *healthcare quality dimensions* sub-module. At *Level 1*, the KB System suggested that SQUH needs to focus on the *sustainable results* sub-module, especially in the dimension of *promoting quality improvement*. For *Level 2*, the analysis shows that SQUH has to concentrate on the dimension of *promoting a quality culture* within the *creating a caring*

*culture* sub-module. At *Level 3*, the KB System suggested that SQUH needs to focus on the *human resources* sub-module, especially as it relates to the *training healthcare providers* dimension. Finally, the KB System has recommended that SQUH has to focus on the *mapping value streams* dimension at Level 4 as part of *pre-implementation L6σ* sub-module.

With regard to **Priority 2** in SQUH, the KB System has suggested that at *Level 0* the dimension of *vision* in the sub-module of *healthcare organisation's statement* need to be improved. Thereafter, at *Level 1* the KB System has identified the sub-module *effective governing body* as Priority 2, specifically within the dimension of *roles and responsibilities*. Then, at *Level 2* the second problematic sub-module is the *planning and designing* (*understanding community health status change* dimension). Next, at *Level 3* the KB System has identified the sub-module *technical resources* as Priority 2, specifically within the dimension of *using equipment*. Finally, at *Level 4* the second KB System recommendation is *Measure* dimension in the *Evaluation of L6σ* sub-module.

Lastly, for **Priority 3**, SQUH has to improve the sub-module *supporting* (*Supporting patient safety culture* dimension), followed by the dimension of *implementing quality management system* in the sub-module *improving quality*, and completed by the dimension of *financial efficiency* in the *physical capital* sub-module.

In relation to RH's validation process, the KB L6σ-QMHE system has clearly shown the **Priority 1**, at *Level 0*, is to focus on the *patient-centred* dimension in the *healthcare quality dimensions* sub-module. At *Level 1*, the KB System suggested that RH needs to focus on the *effective governing body* sub-module, especially in the dimension of *membership*. For *Level 2*, the analysis shows that RH has to concentrate on the dimension of *promoting a quality culture* within the *creating a caring culture* sub-module. At *Level 3*, the KB System suggested that RH needs to focus on the *human*

*resources* sub-module, especially in relation to *training healthcare providers* dimension. Finally, the KB System recommended that RH has to focus on the *mapping value streams* dimension at *Level 4* as part of *pre-implementation L6σ* sub-module.

With regard to **Priority 2** in RH, the KB System has suggested that at *Level 0* the dimension of *values* in the sub-module of *healthcare organisation's statement* need to be improved. Thereafter, at *Level 1* the KB System has identified the sub-module *supporting* as Priority 2, specifically within the dimension of *evaluating the chief executive*. Then, at *Level 2* the second problematic sub-module is the *improving quality* (*Improving client safety* dimension). Next, at *Level 3* the KB System has identified the sub-module *physical capital* as Priority 2, specifically within the dimension of *financial efficiency*. Finally, at *Level 4* the second KB System recommendation is *Analyse* dimension in the *evaluation of L6σ* sub-module.

Lastly, for **Priority 3**, RH has to improve the sub-module *sustainable results* (*Monitoring performance* dimension), followed by the dimension of *planning for community needs* in the sub-module *planning and designing*, and completed by the dimension of *using equipment* in *technical resources* sub-module.

Moving to KH's validation process, the KB L6σ-QMHE system has clearly shown that **Priority 1**, at *Level 0*, is to focus on the *patient-centred* dimension in the *healthcare quality dimensions* sub-module. At *Level 1*, the KB System suggested that KH needs to focus on the *effective governing body* sub-module, especially in the dimension of *membership*. For *Level 2*, the analysis shows that KH has to concentrate on the dimension of *promoting a quality culture* within the *creating a caring culture* sub-module. At *Level 3*, the KB System suggested that KH needs to focus on the *human resources* sub-module, especially in the dimension of *training healthcare providers* dimension.

With regard to **Priority 2** in KH, the KB System has suggested that at *Level 0* the dimension of *values* in the sub-module of *healthcare organisation's statement* need to be improved. Thereafter, at *Level 1* the KB System has identified the sub-module *supporting* as Priority 2, specifically within the dimension of *financial planning*. Then, at *Level 2* the second problematic sub-module is the *improving quality (Managing risk* dimension*).* Next, at *Level 3,* the KB System has identified the sub-module *physical capital* as Priority 2, specifically within the dimension of *financial efficiency*.

Lastly, for **Priority 3**, KH has to improve the sub-module *sustainable results* (*Relations with community* dimension), followed by the dimension of *planning for community needs* in the sub-module *planning and designing*, and completed by the dimension of *using equipment* in the *technical resources* sub-module.

To conclude this summary, The KB-QMHE system has been developed to assess QMHE using GAP tool for benchmarking and AHP for prioritising. The system can help in detecting issues affecting quality of healthcare systems and overcome their challenges. It also can be used as a standard to assess quality management at any healthcare organisation around the globe. Moreover, it suggests primary and secondary solutions based on experts' opinions and functional priorities.

# Chapter 6: Conclusions and Recommendations

## 6.1 Introduction

This chapter summarises the thesis findings considering the importance of the designed approach through the implementation of the KB L6σ-QMHE System. The development process of KB L6σ-QMHE has covered the main strategic and operational issues affecting the L6σ-QMHE environment. The aim of the developed system is to identify the gap between the existing practice and the industry benchmark of QMHE. It also suggests a prioritised action plan to fill the identified gaps. The developed modules include five levels:

- Level 0: Healthcare Organisation's Environment
- Level 1: Healthcare Governance
- Level 2: Healthcare Leadership
- Level 3: Healthcare Organisation's Resources, and
- Level 4: L6σ for QMHE.

## 6.2 Research Achievements

The aim of this research was to design and develop a KBS for integrated L6σ linked to QMHE to create the KB L6σ-QMHE. The system was developed to incorporate GAP analysis and the AHP prioritising technique as a methodology to achieve optimisation and systematic recommendations. The objectives of this research have been successfully achieved in all stages with design, development, implementation, and validation of the KB L6σ-QMHE. The gap between the existing condition and the benchmark is thoroughly evaluated before the final recommendation is made. Therefore, the developed KB L6σ-QMHE system is capable of assisting the healthcare QM

practitioners in their decision-making processes via implementing the L6σ-QMHE. The research activities can be summarised as shown in Figure 6.1.

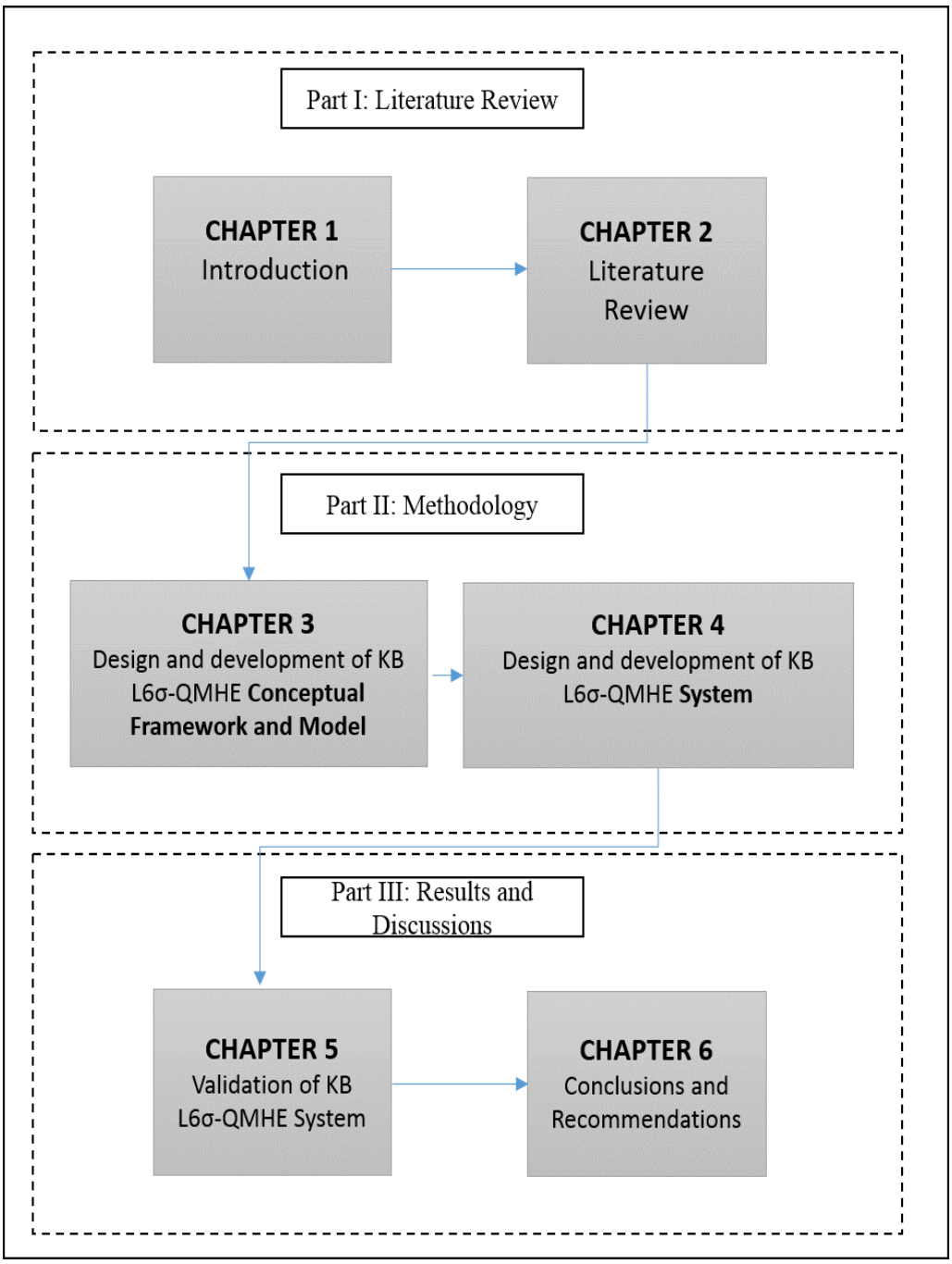


*Figure 6.1 Research activities' outline*

In this research, Chapters 1 proceeded with a background of the problem statement related to the healthcare QM, followed by an extensive literature review in the areas of QMHE, L6σ, and AI in Chapter 2.

Furthermore, in Chapter 1, the research described the background of the present healthcare challenges with a special focus on current issues related to the QM and patient safety; this was to formulate the research aim and objectives. The chapter has also highlighted the research approach that draws the roadmap of integrating L6σ with QMHE using a hybrid KB system embedded with GAP and AHP.

Chapter 2 explained different tools of quality improvements initiatives starting with Lean, followed by TQM, then 6σ and lastly, L6σ. This was followed by the examples of the implementations of each tool in healthcare sectors. Furthermore, it studied the mechanism of L6σ from initiation to evaluation states. The discussion was extended to include AI techniques that are applied in a variety of applications to solve different types of problems, based on each problem field's complexity and uncertainty. Since this research will be using KBS/ES, the components of ES have been discussed in more details. The chapter has also covered the knowledge acquisition and building methods of KBS, along with knowledge representation, and benefits and limitations of ES.

Chapter 3 proposed the KB L6σ-QMHE conceptual framework, which consists of three main stages; these are: Planning (Stage 1), Designing (Stage 2), and Implementation (Stage 3). The conceptual framework was converted into a hybrid KB L6σ model of QMHE that arranged in a decision level hierarchy in which the KPIs. The KB model connects five different levels within the healthcare organisation. These levels are:

- Level 0: Healthcare Organisation's Environment
- Level 1: Healthcare Governance
- Level 2: Healthcare Leadership
- Level 3: Healthcare Organisation's Resources, and
- Level 4: L6σ for QMHE.

By the end of Chapter 3, the research objective *(a)* of developing the conceptual framework and the research objective *(b)* of transforming the conceptual framework into a hybrid KB L6σ model of QMHE have been successfully fulfilled.

Chapter 4 elaborated the detailed development of the KB L6σ-QMHE system based on strategic and operational decision levels. In strategic decision levels, the KBS focused on strategic performance measurement related to Level 0: Healthcare Organisation's Environment, Level 1: Healthcare Governance and Level 2: Healthcare Leadership. Level 0 was used to capture data about the healthcare organisation's statements and about the organisation's quality dimensions. In Level 1, the system focused on capturing data about the organisation's governing body and how it gives support to leaders. Level 2 is last part in the strategic levels and was designed to capture data about the organisation's leaders and how they plan for quality and disasters. It also helped to measure the leadership efforts to form a caring culture among the organisation.

In operational decision levels, the KB system was integrated with two levels: Healthcare Organisation's Resources (level 3), and L6σ for QM at Healthcare (level 4). Level 3 allowed the system to capture data about the organisation's human resources status. It also helped to measure the financial efficiency and the physical environment of the healthcare organisation. Furthermore, level 4 was designed to evaluate the on-going/completed L6σ projects conducted by the healthcare organisation. Therefore, this level assisted in capturing data about the organisation's readiness before implementing L6σ and the degree of success in each phase (within the DMAIC cycle) after the implementation. This chapter has proven the achievement of the research objective *(c)* by converting the KB L6σ-QMHE model into a hybrid system. The chapter also has fulfilled the research objective *(d)* by developing the KB rules of QMHE system. The developed

KB rules have been placed in the ES shell and then integrated into GAP and AHP methodologies.

Chapter 5 discussed the validation process of the KB L6σ-QMHE system which was carried out through three (Oman-based) healthcare organisations: SQUH, RH, and KH. Moreover, the system's contents have been verified via publishing papers in peer-reviewed journals and conference proceedings. The validation results and the detailed discussion were presented in this chapter with the emphasis on using GAP and AHP as a powerful combined methodology. The system was found to be consistent and reliable with the capability of identifying areas of improvements in a priority manner. This was to ensure the KBS's consistency and reliability that fulfil the research objectives *(e) and (f)* by verifying, validating, and refining the hybrid KB L6σ system of QMHE.

Finally, this chapter concludes the research output, highlighting the advantages and limitations of the research. Based on these, the work proposes recommendations for future research by presenting recommendations/suggestions for future research.

### 6.3 Discussion on Research's Contribution to Knowledge

The originality of this research was to develop a KBS to assist healthcare quality managers and practitioners during decision-making in order to achieve excellent benchmark and optimise solutions. The KB L6σ-QMHE system has provided a methodology that begins with identifying the gaps between the current practice and the industry benchmark using a GAP analysis technique. Moreover, it has provided a decision support mechanism that determines the serious and non-serious problems which act as obstacles towards implementing L6σ projects in healthcare environment. It has proven via three case studies (tertiary hospitals) in Oman that it can suggest primary and secondary solutions based on experts' opinions and functional priorities. Since the KBS

has built based on international standards, it can be applied in different countries and with different organisational cultures.

The KB L6σ-QMHE has used a systematic and structured approach that followed defined steps to secure consistency in the approach, and integrated different healthcare management levels to maintain strategic decision-making alignment. The hybrid system has been established to evaluate the healthcare institutional abilities from different angles, starting from a wide strategic level and tightening down to the most operational level. In the strategic decision phase, *Level 0: Healthcare Organisation's Environment*, *Level 1: Healthcare Governance* and *Level 2: Healthcare Leadership*. While in the operational decision phase, *Level 3: Healthcare Organisation's Resources*, and *Level 4: L6σ for QMHE*. Both phases have covered the key aspects of the KB L6σ-QMHE development.

Furthermore, the system was developed in a modular basis approach where each level can be assessed and evaluated separately. This approach has proven the ability of the system to benchmark each KPI in the module and provide its prioritisation in the suggested road map. As a result, there is flexibility as any update of knowledge within any stage can be easily amended from reviewing international healthcare standards, latest literature publications, and interviewing healthcare QM experts and L6σ MBB.

### 6.4 Limitations of the Research

Although the developed KB L6σ-QMHE system has demonstrated potential in recommending and suggesting improvements for QMHE, the system is still at the prototype development stage. Thus, some limitations are still valid as described below:

- It is difficult to benchmark the performance effectiveness (in terms of functionality and acceptance) of the KB L6σ-QMHE system due to unavailability of a system designed to integrate QMHE with L6σ.

- The development of the KB rules only focuses on the important areas to be improved within the L6σ-QMHE context. Nevertheless, there are unlimited rules that could be implemented in QMHE environment, which become impossible to include in such a limited scope.
- This research used the explanation facility to overcome the uncertainty factor instead of using fuzzy logic or Bayesian logic. Thus, the assumption that the organisation's participant understands the system's questions with related explanations must be taken into account.
- The developed KB L6σ-QMHE system is considered similar to other KBS initiatives. According to Mosqueira-Rey et al. (2008), a KBS is considered to be a 'black box' in the validation process, where the user can see only the output as a result of a set of inputs evaluated. This is because the reasoning, and the rules development process, have been carried out by the knowledge engineer with the assistance of human experts in the field of L6σ-QMHE. Therefore, the organisation's management level may not appreciate the working effort in developing the KBS as it is difficult to let them visualise the reasoning process inside the system.

## 6.5 Recommendations for Future Work

There are some recommendations for the KB L6σ-QMHE system future work which require improvement as explained in the following points:

- This research contains 964 KB rules forming the KB L6σ-QMHE system. Thus, for the above suggested areas of expansion, it is recommended that another 3000 rules be added to the developed KB system.
- This research was focusing more on non-clinical healthcare rules to cover QM aspects. It is recommended for each field (clinical, technical and administrative)

in healthcare to build its own system to enhance the performance by identifying gaps and prioritise them accordingly.

- The industrial validation process was performed in an Omani healthcare environment, which differs from many other countries in terms of regulations, practice, and culture. Therefore, the KB L6σ-QMHE system is recommended to be implemented and validated in other countries, which have different culture, and strict policies, and regulations with respect to QMHE.

### 6.6 Final Remarks

This chapter has wrapped up the research outcomes by discussing the planning, designing, and implementation stages of the KB L6σ-QMHE system. The development process has determined five main modules (levels) to focus on. These levels incorporated GAP analysis and the AHP technique which were embedded in the system. In addition, this chapter has identified the research achievements based on the main objectives declared in Chapter 1. It has also discussed the contribution of the KB L6σ-QMHE system, the research limitations, and the recommendations for future work. It has proven the consistency and reliability of the KB L6σ-QMHE system which provides a proper guiding tool for the decision-makers in QMHE.

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# Appendix A

RE: Reminder: Permission request

Carey Guilbeault <Carey.Guilbeault@accreditation.ca>

Tue 30/08/2016 14:42

To:Yousuf Nasser Al Khamisi <Y.N.M.AlKhamisi@bradford.ac.uk>;

Cc:Yusufsquh@gmail.com <Yusufsquh@gmail.com>;

Yousuf,
You may use the discount code 2QIFREE to access the desired standards.
Best regards,
Carey

---

**From:** Sébastien Audette **On Behalf Of** Mailbox International
**Sent:** Monday, August 29, 2016 11:19 PM
**To:** Carey Guilbeault
**Subject:** FW: Reminder: Permission request

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**From:** Yousuf Nasser Al Khamisi [mailto:Y.N.M.AlKhamisi@bradford.ac.uk]
**Sent:** August 29, 2016 7:12 AM
**To:** Mailbox International <international@accreditation.ca>
Cc: Yusufsquh@gmail.com
**Subject:** Reminder: Permission request

Dear Sir / Mdm

**This is to remind you about my last week email**

I am an Omani PhD student studying at University of Bradford, UK sponsored by Sultan Qaboos University Hospital (SQUH) which had been accredited by ACI since 2014.

Part of my PhD is to develop a quality management model in healthcare environments.

Therefore, I am seeking your permission to use ACI **Governance standard** and ACI **Leadership standard** as a part of this model with the respect of referencing both of them accordingly.

**For any further clarification, please contact me**

Kind regards,

# Appendix B

*Table A.1 List of Experts in Healthcare Quality Management and Lean Six Sigma MBB practitioners interviewed by the researcher From 10 July to 20 August 2017*

| | Expert's Name | Position | Organisation |
|---|---|---|---|
| **1** | Dr. Ahmed Al Mandhari | WHO Regional Director for the Eastern Mediterranean | WHO |
| **2** | Dr. Rashid Al Abri | Associated Professor, Head of Medical Education, College of medicine and Health sciences | Sultan Qaboos University Oman |
| **3** | Dr. Maha Al Shuaibi | Director of Development and Quality | Sultan Qaboos University Hospital Oman |
| **4** | Dr. Yasmeen Al Hatmi | Deputy Director of Development and Quality | Sultan Qaboos University Hospital Oman |
| **5** | Mr. Hamdan Al Siyabi | Head of Quality Monitoring | Sultan Qaboos University Hospital Oman |
| **6** | Dr. Mahmood Al Kindi | Assistant Professor, Mechanical and Industrial Engineering, College of Engineering | Sultan Qaboos University Oman |
| **7** | Dr. Sujan Piya | Assistant Professor, (Medical Eng. Lecturer), Mechanical and Industrial Engineering, College of Engineering | Sultan Qaboos University Oman |
| **8** | Mr. Mustafa Al Balushi | Business Improvement Consultant, Master Black Belt in Lean Six Sigma | Oman Aluminium Rolling Oman |

# Appendix C

UNIVERSITY of BRADFORD

***Interview Form***

| | | |
|---|---|---|
| 1 | **Expert's name** | Dr. Ahmed Al-Mandhari |
| 2 | **Position** | Director General - QAC - MoH - Oman |
| 3 | **Organisation** | MoH |
| 4 | **Date** | 10/7/17 |
| 5 | **Researcher** | Yousuf Al Khamisi, PhD student |

| Strategic Level | Stage 1 : Planning |
|---|---|

**Level 0: Healthcare Organization's Environment**

**Healthcare quality Dimensions**

**Patient centred**

1- Definition
2- engagement
3- empowernet
4- multi-disciplinary teams
5- involvement
6- H/E
7- pt. support groups

**Accessibility**

1- Definition
2- Geographic
3- Financial:
4- waiting for appt. in clinic (PC-5)
5- daily waiting
6- distance
7-

**Effectiveness**

1- Definition
2- Average # of pt. visit in A/E (PC-5)
3- Finance: - asthma, epileptic attack
4- waste mgt: - (PC-3) - policy (in changing behaviour)
5- infection rate (PC-7)

**Healthcare organization's statement**

**Vision**

- Health
- research
- Education

**Objectives**

**Mission**

your ~~re~~organization

**Values**

- team work
- transparency
- dignity
- respect
- support
- openness

# Appendix **D**

UNIVERSITY of BRADFORD
School of Engineering

**Professor Mohammed Khurshid Khan**
BEng PhD MBA CEng FIMechE
**Professor of Manufacturing Systems Engineering**
Tel: + 44 (0)1274 234523
Mob: + 44 (0)7766 248372
Email: m.k.khan@bradford.ac.uk

28th April 2017

**To Whom It May Concern.**

**Subject: Mr. Yousuf Al Khamisi: Research KB Model Fieldwork.**

Mr. Yousuf Al Khamisi is studying for a PhD in the School of Engineering. He is being supervised by me and Dr. Eduardo Munive. The title of his PhD study is **"The Design and Development of a Knowledge-Based Lean Six Sigma System for Healthcare Management".** In essence, this is an application of Artificial Intelligence (AI) and Lean Six-Sigma methodologies for assisting in decision making for achieving benchmark standards for a healthcare environment. **He will be carrying out fieldwork in Oman during 26th June to 3rd September 2017.**

Thus the KB system contributes to healthcare management and can be used by organisations which aim to achieve excellence in this area in order to achieve optimum patient care and environmental goals.

An important aspect of this research is the development of the Knowledge Rules for the AI KB system in a real environment. To that end, we would be grateful for your input and contribution in this aspect of the work. You and your organisation have been chosen for your cutting edge knowledge and application in the chosen field.

We can confirm that that your participation (no more than 3 hours are envisaged for the validation) will be anonymous and confidential, unless you desire to be acknowledged. In addition, we shall be sharing the full results of the validation with your selves.

We are grateful for your assistance and time, and thank you in advance.
Yours faithfully,

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BD7 1DP, UK

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# Appendix E

UNIVERSITY of BRADFORD
School of Engineering

TO: Whom it may concern,

FROM: Dr J. Eduardo Munive-Hernandez

DATE: 13th November 2017

SUBJECT: Letter in support of Mr. Yousuf Al Khamsi, validation of Knowledge-based System for Lean Six Sigma implementation in health care, PhD project.

To whom it may concern:

Mr. Yousuf Al Khamisi is currently a PhD student at the Faculty of Engineering and Informatics, University of Bradford. Mr Al Khamsi is being supervised by myself and by Professor Khurshid Khan. The PhD research project of Mr Al Khamisi is related to the development of a knowledge-based system to support the implementation of Lean Six-Sigma principles in health care organisations. The purpose of the system is to assist decision-making in prioritising actions to enhance the performance of healthcare organisations, with a main focus on quality management.

A very important aspect of this research is the validation of this system with inputs from a real health care environment.

For that reason we would be very grateful if you were willing to contribution with your inputs in this validation process. We will be happy to share with you the results of this exercise and provide you with some valuable feedback. We won't disclose the name of the participant organisation or individuals in our reports to maintain the identity of the organisation confidential.

Mr Al Khamsi is planning to arrange interviews with health care organisations in Oman to validate the system between the 13th of December 2017 and the 10th of January 2018.

We will be very grateful for your support to validate this system. Please, do not hesitate to contact me if you have any question regarding this letter.

Yours faithfully,

Dr J. Eduardo Munive H.,
Lecturer in Advanced Manufacturing Engineering,
University of Bradford,
School of Engineering,
Bradford, BD7 1DP
Office: Chesham Building C2.24
Phone: +44 (0)1274 23 3710
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# Appendix F

## Royal Hospital GAP and AHP analysis tables

*Table F.1 GAP analysis results of Royal Hospital Environment*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Healthcare Organisational statement** | Vision | **19** | **12** | **7** | **4** | **2** | **1** | **0** | **0** |
| | Mission | **19** | **15** | **4** | **0** | **3** | **1** | **0** | **0** |
| | Values | **14** | **1** | **13** | **1** | **8** | **4** | **0** | **0** |
| | **Sub-total** | **52** | **28** | **24** | **5** | **13** | **6** | **0** | **0** |
| **Healthcare Quality Dimensions** | Accessibility | **9** | **0** | **9** | **3** | **0** | **2** | **4** | **0** |
| | Patient-centred | **30** | **7** | **23** | **7** | **1** | **5** | **10** | **0** |
| | Effectiveness | **24** | **4** | **20** | **4** | **0** | **4** | **12** | **0** |
| | **Sub-total** | **63** | **11** | **52** | **14** | **1** | **11** | **26** | **0** |
| **Total** | | **115** | **39** | **76** | **19** | **14** | **17** | **26** | **0** |

*Table F.2 GAP analysis results of Royal Hospital Governance*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Effective Governing Body** | Roles and responsibilities | **29** | **12** | **17** | **17** | **0** | **0** | **0** | **0** |
| | Membership | **53** | **9** | **44** | **4** | **16** | **24** | **0** | **0** |
| | Decision-making | **11** | **11** | **0** | **0** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **93** | **32** | **61** | **21** | **16** | **24** | **0** | **0** |
| **Supporting** | Evaluating the CEO | **15** | **7** | **8** | **0** | **6** | **2** | **0** | **0** |
| | Financial planning | **28** | **27** | **1** | **0** | **1** | **0** | **0** | **0** |
| | Supporting patient safety culture | **11** | **10** | **1** | **1** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **54** | **44** | **10** | **1** | **7** | **2** | **0** | **0** |
| **Sustainable Results** | Relations with community | **21** | **21** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Promoting quality improvement | **18** | **14** | **4** | **0** | **4** | **0** | **0** | **0** |
| | Monitoring performance | **26** | **21** | **5** | **3** | **2** | **0** | **0** | **0** |
| | **Sub-total** | **65** | **56** | **9** | **3** | **6** | **0** | **0** | **0** |
| **Total** | | **212** | **132** | **80** | **25** | **29** | **26** | **0** | **0** |

*Table F.3 GAP analysis results of Royal Hospital Leadership*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Creating a caring culture** | Decisions according values | **28** | **28** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Promoting a safe work environment | **40** | **37** | **3** | **0** | **0** | **0** | **3** | **0** |
| | Promoting a quality culture | **44** | **7** | **37** | **0** | **0** | **15** | **22** | **0** |
| | **Sub-total** | **112** | **72** | **40** | **0** | **0** | **15** | **25** | **0** |
| **Planning and designing** | Planning for community needs | **80** | **71** | **9** | **0** | **5** | **4** | **0** | **0** |
| | Understanding community health status change | **34** | **28** | **6** | **3** | **1** | **2** | **0** | **0** |
| | Developing an operational plans | **46** | **38** | **8** | **0** | **0** | **7** | **1** | **0** |
| | **Sub-total** | **160** | **137** | **23** | **3** | **6** | **13** | **1** | **0** |
| **Planning for disasters** | Preparing for disasters and emergencies | **44** | **42** | **2** | **0** | **1** | **1** | **0** | **0** |
| | **Sub-total** | **44** | **42** | **2** | **0** | **1** | **1** | **0** | **0** |
| **Improving quality** | Managing Risk | **20** | **20** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Improving client flow | **14** | **10** | **4** | **2** | **1** | **1** | **0** | **0** |
| | Improving client safety | **21** | **7** | **14** | **7** | **4** | **3** | **0** | **0** |
| | Implementing a quality management system | **13** | **4** | **9** | **0** | **0** | **3** | **6** | **0** |
| | **Sub-total** | **68** | **41** | **27** | **9** | **5** | **7** | **6** | **0** |
| **Total** | | **384** | **292** | **92** | **12** | **12** | **36** | **32** | **0** |

*Table F.4 GAP analysis results of Royal Hospital resources*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Human resources** | Training of Healthcare providers | **54** | **11** | **43** | **0** | **10** | **18** | **15** | **0** |
| | **Sub-total** | **54** | **11** | **43** | **0** | **10** | **18** | **15** | **0** |
| **Physical Capital** | Financial efficiency | **22** | **13** | **9** | **0** | **1** | **1** | **7** | **0** |
| | Physical environment | **21** | **17** | **4** | **0** | **0** | **0** | **4** | **0** |
| | **Sub-total** | **43** | **30** | **13** | **0** | **1** | **1** | **11** | **0** |
| **Technical resources** | Using equipment | **20** | **12** | **8** | **0** | **0** | **0** | **8** | **0** |
| | Information management | **24** | **20** | **4** | **0** | **2** | **1** | **1** | **0** |
| | **Sub-total** | **44** | **32** | **12** | **0** | **2** | **1** | **9** | **0** |
| **Total** | | **141** | **73** | **68** | **0** | **13** | **20** | **35** | **0** |

*Table F.5 GAP analysis results of Royal Hospital L6σ of Quality Management*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Pre-implementing L6σ** | Identifying service | **27** | **21** | **6** | **0** | **2** | **4** | **0** | **0** |
| | Mapping Value streams | **41** | **21** | **20** | **0** | **3** | **17** | **0** | **0** |
| | **Sub-total** | **68** | **42** | **26** | **0** | **5** | **21** | **0** | **0** |
| **Evaluating L6σ** | Define | **16** | **15** | **1** | **0** | **0** | **1** | **0** | **0** |
| | Measure | **10** | **8** | **2** | **0** | **2** | **0** | **0** | **0** |
| | Analyse | **5** | **2** | **3** | **0** | **3** | **0** | **0** | **0** |
| | Improve | **6** | **5** | **1** | **0** | **0** | **1** | **0** | **0** |
| | Control | **7** | **6** | **1** | **0** | **0** | **1** | **0** | **0** |
| | **Sub-total** | **44** | **36** | **8** | **0** | **5** | **3** | **0** | **0** |
| **Total** | | **112** | **78** | **34** | **0** | **10** | **24** | **0** | **0** |

*Table F.6 Level 0: AHP analysis with PV for RH*

| **Level 0** | Healthcare Organisational statement | Healthcare Quality Dimensions | P.V |
|---|---|---|---|
| Healthcare Organisational statement | 1 | 1/2 | 0.333 |
| Healthcare Quality Dimensions | 2 | 1 | **0.667** |

*Table F.7 Level 1: AHP analysis with PV for RH*

| **Level 1** | Effective Governing Body | Supporting | Sustainable Results | P.V |
|---|---|---|---|---|
| Effective Governing Body | 1 | 2 | 3 | **0.54** |
| Supporting | 1/2 | 1 | 2 | 0.297 |
| Sustainable Results | 1/3 | 1/2 | 1 | 0.163 |

*TableF.8 Level 2: AHP analysis with PV for RH*

| **Level 2** | Creating a caring culture | Planning and designing | Planning for disasters | Improving quality | P.V |
|---|---|---|---|---|---|
| Creating a caring culture | 1 | 3 | 4 | 2 | **0.467** |
| Planning and designing | 1/3 | 1 | 2 | 1/2 | 0.160 |
| Planning for disasters | 1/4 | 1/2 | 1 | 1/3 | 0.095 |
| Improving quality | 1/2 | 2 | 3 | 1 | 0.277 |

*TableF.9 Level 3: AHP analysis with PV for RH*

| **Level 3** | Human resources | Physical capital | Technical resources | P.V |
|---|---|---|---|---|
| Human resources | 1 | 2 | 3 | **0.54** |
| Physical capital | 1/2 | 1 | 2 | 0.297 |
| Technical resources | 1/3 | 1/2 | 1 | 0.163 |

*Table F.10 Level 4: AHP analysis with PV for RH*

| **Level 4** | Pre-implementing L6σ | Evaluating L6σ | P.V |
|---|---|---|---|
| Pre-implementing L6σ | 1 | 2 | **0.667** |
| Evaluating L6σ | 1/2 | 1 | 0.333 |

*Table F.11 Healthcare Organisational statement AHP analysis with PV for RH*

| **Healthcare Organisational statement** | Vision | Mission | Values | P.V |
|---|---|---|---|---|
| Vision | 1 | 1 | 1/2 | 0.25 |
| Mission | | 1 | 1/2 | 0.25 |
| Values | 2 | 2 | 1 | **0.5** |

*Table F.12 Healthcare Quality Dimensions AHP analysis with PV for RH*

| **Healthcare Quality Dimensions** | Accessibility | Patient-centred | Effectiveness | P.V |
|---|---|---|---|---|
| Accessibility | 1 | 1/3 | 1/2 | 0.163 |
| Patient-centred | 3 | 1 | 2 | **0.540** |
| Effectiveness | 2 | 1/2 | 1 | 0.297 |

*Table F.13 Effective Governing Body AHP analysis with PV for RH*

| **Effective Governing Body** | Roles and responsibilities | Membership | Decision making | P.V |
|---|---|---|---|---|
| Roles and responsibilities | 1 | 1/2 | 2 | 0.297 |
| Membership | 2 | 1 | 3 | **0.540** |
| Decision making | 1/2 | 1/3 | 1 | 0.163 |

*Table F.14 Supporting AHP analysis with PV for RH*

| **Supporting** | Evaluating the CEO | Financial planning | Supporting patient safety culture | P.V |
|---|---|---|---|---|
| Evaluating the CEO | 1 | 2 | 2 | **0.5** |
| Financial planning | 1/2 | 1 | 1 | 0.25 |
| Supporting patient safety culture | 1/2 | 1 | 1 | 0.25 |

*Table F.15 Sustainable Results AHP analysis with PV for RH*

| **Sustainable Results** | Relations with community | Promoting quality improvement | Monitoring performance | P.V |
|---|---|---|---|---|
| Relations with community | 1 | 2/3 | 1/2 | 0.221 |
| Promoting quality improvement | 3/2 | 1 | 2/3 | 0.319 |
| Monitoring performance | 2 | 3/2 | 1 | **0.460** |

*Table F.16 Creating a caring culture AHP analysis with PV for RH*

| **Creating a caring culture** | Decisions according values | Promoting a safe work environment | Promoting a quality culture | P.V |
|---|---|---|---|---|
| Decisions according values | 1 | 2/3 | 1/3 | 0.182 |
| Promoting a safe work environment | 3/2 | 1 | 1/2 | 0.273 |
| Promoting a quality culture | 3 | 2 | 1 | **0.545** |

*Table F.17 Planning and designing AHP analysis with PV for RH*

| **Planning and designing** | Planning for community needs | Understanding community health status change | Developing an operational plans | P.V |
|---|---|---|---|---|
| Planning for community needs | 1 | 3 | 2 | **0.540** |
| Understanding community health status change | 1/3 | 1 | 1/2 | 0.163 |
| Developing an operational plans | 1/2 | 2 | 1 | 0.297 |

*Table F.18 Improving quality AHP analysis with PV for RH*

| **Improving quality** | Managing Risk | Improving client flow | Improving client safety | Implementing a quality management system | P.V |
|---|---|---|---|---|---|
| Managing Risk | 1 | 1/2 | 1/4 | 1/3 | 0.10 |
| Improving client flow | 2 | 1 | 1/2 | 2/3 | 0.199 |
| Improving client safety | 4 | 2 | 1 | 3/2 | **0.411** |
| Implementing a quality management system | 3 | 3/2 | 2/3 | 1 | 0.290 |

*Table F.19 Physical capital AHP analysis with PV for RH*

| **Physical capital** | Financial efficiency | Physical environment | P.V |
|---|---|---|---|
| Financial efficiency | 1 | 2 | **0.667** |
| Physical environment | 1/2 | 1 | 0.333 |

*Table F.20 Technical resources AHP analysis with PV for RH*

| **Technical resources** | Using equipment | Information management | P.V |
|---|---|---|---|
| Using equipment | 1 | 2 | **0.667** |
| Information management | 1/2 | 1 | 0.333 |

*Table F.21 Pre-implementing L6σ AHP analysis with PV for RH*

| **Pre-implementing L6σ** | Identifying service | Mapping value streams | P.V |
|---|---|---|---|
| Identifying service | 1 | 1/2 | 0.333 |
| Mapping value streams | 2 | 1 | **0.667** |

*Table F.22 Evaluating L6σ L6σ AHP analysis with PV for RH*

| **Evaluating L6σ** | Define | Measure | Analyse | Improve | Control | P.V |
|---|---|---|---|---|---|---|
| Define | 1 | 2/3 | 1/3 | 1 | 1 | 0.133 |
| Measure | 2/3 | 1 | 1/2 | 3/2 | 3/2 | 0.20 |
| Analyse | 3 | 2 | 1 | 3 | 3 | **0.40** |
| Improve | 1 | 2/3 | 1/3 | 1 | 1 | 0.133 |
| Control | 1 | 2/3 | 1/3 | 1 | 1 | 0.133 |

# Appendix G

## Khoula Hospital GAP and AHP analysis tables

*Table G.1 GAP analysis results of Khoula Hospital Environment*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Healthcare Organisational statement** | Vision | **19** | **19** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Mission | **19** | **10** | **9** | **7** | **2** | **0** | **0** | **0** |
| | Values | **14** | **2** | **12** | **0** | **8** | **4** | **0** | **0** |
| | **Sub-total** | **52** | **31** | **21** | **7** | **10** | **4** | **0** | **0** |
| **Healthcare Quality Dimensions** | Accessibility | **9** | **0** | **9** | **3** | **2** | **3** | **1** | **0** |
| | Patient-centred | **30** | **11** | **19** | **3** | **1** | **4** | **11** | **0** |
| | Effectiveness | **24** | **10** | **14** | **2** | **2** | **4** | **6** | **0** |
| | **Sub-total** | **63** | **21** | **42** | **8** | **5** | **11** | **18** | **0** |
| **Total** | | **115** | **52** | **63** | **15** | **15** | **15** | **18** | **0** |

*Table G.2 GAP analysis results of Khoula Hospital Governance*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Effective Governing Body** | Roles and responsibilities | **29** | **25** | **4** | **4** | **0** | **0** | **0** | **0** |
| | Membership | **53** | **26** | **27** | **4** | **13** | **10** | **0** | **0** |
| | Decision-making | **11** | **10** | **1** | **0** | **0** | **1** | **0** | **0** |
| | **Sub-total** | **93** | **61** | **32** | **8** | **13** | **11** | **0** | **0** |
| **Supporting** | Evaluating the CEO | **15** | **9** | **6** | **0** | **5** | **1** | **0** | **0** |
| | Financial planning | **28** | **20** | **8** | **1** | **7** | **0** | **0** | **0** |
| | Supporting patient safety culture | **11** | **7** | **4** | **4** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **54** | **36** | **18** | **5** | **12** | **1** | **0** | **0** |
| **Sustainable Results** | Relations with community | **21** | **13** | **8** | **0** | **2** | **3** | **3** | **0** |
| | Promoting quality improvement | **18** | **13** | **5** | **0** | **5** | **0** | **0** | **0** |
| | Monitoring performance | **26** | **23** | **3** | **3** | **0** | **0** | **0** | **0** |
| | **Sub-total** | **65** | **49** | **16** | **3** | **7** | **3** | **3** | **0** |
| **Total** | | **212** | **146** | **66** | **16** | **32** | **15** | **3** | **0** |

*Table G.3 GAP analysis results of Khoula Hospital Leadership*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Creating a caring culture** | Decisions according values | **28** | **25** | **3** | **0** | **0** | **1** | **2** | **0** |
| | Promoting a safe work environment | **40** | **25** | **15** | **0** | **0** | **14** | **1** | **0** |
| | Promoting a quality culture | **44** | **0** | **44** | **2** | **3** | **0** | **39** | **0** |
| | **Sub-total** | **112** | **50** | **62** | **2** | **3** | **15** | **42** | **0** |
| **Planning and designing** | Planning for community needs | **80** | **73** | **7** | **0** | **1** | **6** | **0** | **0** |
| | Understanding community health status change | **34** | **32** | **2** | **1** | **0** | **1** | **0** | **0** |
| | Developing an operational plans | **46** | **42** | **4** | **0** | **0** | **3** | **1** | **0** |
| | **Sub-total** | **160** | **147** | **13** | **1** | **1** | **10** | **1** | **0** |
| **Planning for disasters** | Preparing for disasters and emergencies | **44** | **38** | **6** | **0** | **2** | **4** | **0** | **0** |
| | **Sub-total** | **44** | **38** | **6** | **0** | **2** | **4** | **0** | **0** |
| **Improving quality** | Managing Risk | **20** | **0** | **20** | **0** | **5** | **15** | **0** | **0** |
| | Improving client flow | **14** | **14** | **0** | **0** | **0** | **0** | **0** | **0** |
| | Improving client safety | **21** | **9** | **12** | **3** | **6** | **3** | **0** | **0** |
| | Implementing a quality management system | **13** | **4** | **9** | **3** | **0** | **1** | **5** | **0** |
| | **Sub-total** | **68** | **27** | **41** | **6** | **11** | **19** | **5** | **0** |
| **Total** | | **384** | **262** | **122** | **9** | **17** | **48** | **48** | **0** |

*Table G.4 GAP analysis results of Khoula Hospital resources*

| Sub-module | Dimensions | No. of KB rules | GPs | BPs | PCs of BPs | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| **Human resources** | Training of Healthcare providers | **54** | **1** | **53** | **0** | **8** | **36** | **9** | **0** |
| | **Sub-total** | **54** | **1** | **53** | **0** | **8** | **36** | **9** | **0** |
| **Physical Capital** | Financial efficiency | **22** | **14** | **8** | **0** | **0** | **3** | **5** | **0** |
| | Physical environment | **21** | **14** | **7** | **0** | **3** | **0** | **4** | **0** |
| | **Sub-total** | **43** | **28** | **15** | **0** | **3** | **3** | **9** | **0** |
| **Technical resources** | Using equipment | **20** | **12** | **8** | **0** | **0** | **0** | **8** | **0** |
| | Information management | **24** | **20** | **4** | **0** | **2** | **1** | **1** | **0** |
| | **Sub-total** | **44** | **32** | **12** | **0** | **2** | **1** | **9** | **0** |
| **Total** | | **141** | **61** | **80** | **0** | **13** | **40** | **27** | **0** |

*Table G.5 Level 0: AHP analysis with PV for KH*

| **Level 0** | Healthcare Organisational statement | Healthcare Quality Dimensions | P.V |
|---|---|---|---|
| Healthcare Organisational statement | 1 | 1/2 | 0.333 |
| Healthcare Quality Dimensions | 2 | 1 | **0.667** |

*Table G.6 Level 1: AHP analysis with PV for KH*

| **Level 1** | Effective Governing Body | Supporting | Sustainable Results | P.V |
|---|---|---|---|---|
| Effective Governing Body | 1 | 2 | 3 | **0.540** |
| Supporting | 1/2 | 1 | 2 | 0.297 |
| Sustainable Results | 1/3 | 1/2 | 1 | 0.163 |

*Table G.7 Level 2: AHP analysis with PV for KH*

| **Level 2** | Creating a caring culture | Planning and designing | Planning for disasters | Improving quality | P.V |
|---|---|---|---|---|---|
| Creating a caring culture | 1 | 3 | 4 | 2 | **0.467** |
| Planning and designing | 1/3 | 1 | 2 | 1/2 | 0.16 |
| Planning for disasters | 1/4 | 1/2 | 1 | 1/3 | 0.095 |
| Improving quality | 1/2 | 2 | 3 | 1 | 0.277 |

*Table G.8 Level 3: AHP analysis with PV for KH*

| **Level 3** | Human resources | Physical capital | Technical resources | P.V |
|---|---|---|---|---|
| Human resources | 1 | 3/2 | 3 | **0.5** |
| Physical capital | 2/3 | 1 | 2 | 0.333 |
| Technical resources | 1/3 | 1/2 | 1 | 0.167 |

*Table G.9 Healthcare Organisational statement AHP analysis with PV for KH*

| **Healthcare Organisational statement** | Vision | Mission | Values | P.V |
|---|---|---|---|---|
| Vision | 1 | 1/2 | 1/3 | 0.163 |
| Mission | 2 | 1 | 1/2 | 0.297 |
| Values | 3 | 2 | 1 | **0.540** |

*Table G.10 Healthcare Quality Dimensions AHP analysis with PV for KH*

| **Healthcare Quality Dimensions** | Accessibility | Patient-centred | Effectiveness | P.V |
|---|---|---|---|---|
| Accessibility | 1 | 1/3 | 1/2 | 0.167 |
| Patient-centred | 3 | 1 | 3/2 | **0.50** |
| Effectiveness | 2 | 2/3 | 1 | 0.333 |

*Table G.11 Effective Governing Body AHP analysis with PV for KH*

| **Effective Governing Body** | Roles and responsibilities | Membership | Decision making | P.V |
|---|---|---|---|---|
| Roles and responsibilities | 1 | 1/2 | 2 | 0.297 |
| Membership | 2 | 1 | 3 | **0.540** |
| Decision making | 1/2 | 1/3 | 1 | 0.163 |

*Table G.12 Supporting AHP analysis with PV for KH*

| **Supporting** | Evaluating the CEO | Financial planning | Supporting patient safety culture | P.V |
|---|---|---|---|---|
| Evaluating the CEO | 1 | 1/2 | 3/2 | 0.273 |
| Financial planning | 2 | 1 | 3 | **0.545** |
| Supporting patient safety culture | 1/3 | 2/3 | 1 | 0.182 |

*Table G.13 Sustainable Results AHP analysis with PV for KH*

| **Sustainable Results** | Relations with community | Promoting quality improvement | Monitoring performance | P.V |
|---|---|---|---|---|
| Relations with community | 1 | 2 | 3 | **0.545** |
| Promoting quality improvement | 1/2 | 1 | 3/2 | 0.273 |
| Monitoring performance | 1/3 | 2/3 | 1 | 0.182 |

*Table G.14 Creating a caring culture AHP analysis with PV for KH*

| **Creating a caring culture** | Decisions according values | Promoting a safe work environment | Promoting a quality culture | P.V |
|---|---|---|---|---|
| Decisions according values | 1 | 2/3 | 1/3 | 0.182 |
| Promoting a safe work environment | 3/2 | 1 | 1/2 | 0.273 |
| Promoting a quality culture | 3 | 2 | 1 | **0.545** |

*Table G.15 Planning and designing AHP analysis with PV for KH*

| **Planning and designing** | Planning for community needs | Understanding community health status change | Developing an operational plans | P.V |
|---|---|---|---|---|
| Planning for community needs | 1 | 3 | 2 | **0.545** |
| Understanding community health status change | 1/3 | 1 | 2/3 | 0.182 |
| Developing an operational plans | 1/2 | 3/2 | 1 | 0.273 |

*Table G.16 Improving quality AHP analysis with PV for KH*

| **Improving quality** | Managing Risk | Improving client flow | Improving client safety | Implementing a quality management system | P.V |
|---|---|---|---|---|---|
| Managing Risk | 1 | 4 | 2 | 3 | **0.478** |
| Improving client flow | 1/4 | 1 | 1/3 | 1/2 | 0.134 |
| Improving client safety | 1/2 | 3 | 1 | 3/2 | 0.207 |
| Implementing a quality management system | 1/3 | 2 | 2/3 | 1 | 0.181 |

*Table G.17 Physical capital AHP analysis with PV for KH*

| **Physical capital** | Financial efficiency | Physical environment | P.V |
|---|---|---|---|
| Financial efficiency | 1 | 2 | **0.667** |
| Physical environment | 1/2 | 1 | 0.333 |

*Table G.18 Technical resources AHP analysis with PV for KH*

| **Technical resources** | Using equipment | Information management | P.V |
|---|---|---|---|
| Using equipment | 1 | 2 | **0.667** |
| Information management | 1/2 | 1 | 0.333 |